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# Deepening Inquiry: What Processes of Making Music Can Teach Us about Creativity and Ontology for Inquiry Based Science Education

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**Abstract**

Drawing from their respective work at the intersection of music and science, the co-authors argue that engaging in processes of making music can help students more deeply engage in the kinds of creativity associated with inquiry based science education (IBSE) and scientists better convey their ideas to others. Of equal importance, the processes of music making can provide students a means to experience another central aspect of IBSE, the liminal ontological experience of being utterly lost in the inquiry process. This piece is also part of burgeoning studies documenting the use of the arts in STEM education (STEAM).

> *Principles for the Development of a Complete Mind: Study the science of art. Study the art of science. Develop your senses – especially learn how to see. Realize that everything connects to everything else.*
> – Leonardo da Vinci

## Introduction

Sounds are educational (Gershon, 2011a). They help us understand not only ourselves in relation to others, but also strongly inform our comprehension about the ecologies in which we live (e.g. Erlmann, 2004; Feld, 1996, 2000; Gershon, 2013a; Peña, Mehler &Nespor, 2011). Of similar importance, whether through a teacher's voice, a child's laugh, or the wail of a tornado siren, we learn through sound (Feld, 1982; Gershon, 2011a; Schafer, 1977; Sterne, 2003). In these ways, the sonic is not only a site of teaching and learning but also a means for communicating knowledge, regardless of their intentionality[1].

A key aspect of our respective identities compounds our interest in the educational capacities of sounds—both authors are educators and working musicians. As we describe below, these interests in the educational possibilities for sounds have combined to create research projects that focus on the intersection of science, music, and how educational actors make sense.

Over the course of several conversations about our continuing scholarship we came to realize that we had independently arrived upon very similar understandings about the relationships between music, sound and inquiry-based science education (IBSE). The first of these understandings was a recognition that our engagement in processes of music-making our lives as musicians taught us about how we might better conceptualize what inquiry-based science education might mean and how it can function. Second, we both found that music-making helped the students, teachers, and scientists with whom we work improve their processes of scientific inquiry in two congruent yet markedly different contexts—city schools in the United States and members of the scientific community throughout Europe. Additionally, the experiences related in this article were fundamental to the development of ideas on which the European Union's "Implementing Creative Strategies Into Science Teaching (CREAT-IT)" project are based. Oded is that project's Coordinator, while Walter is a visiting scholar at the institution coordinating CREAT-IT, Stord Haugesund University College in Norway, and has acted as a "critical friend" during its recently completed developmental phase. Finally, through our respective projects at the intersection of music and science, an important understanding about the ontological nature of making music emerged for each of us

[1] Along similar lines, it is important to note that sound can be as disabling as it can be enabling (cf. Lane, 1993; Goodale, 2011; Sterne, 2005). While we wish to acknowledge these limitations, we believe this discussion warrants a space of its own and our focus here is on the more enabling aspects of sound, particularly as talk and music.

independently. We found that processes of making music helped to foster an important and paradoxical-seeming aspect of inquiry, the liminal moment of simultaneously being lost in process and completely present in that moment.

As a result of these and other similar findings, on one hand, our work here can be understood as part of the movement from STEM (Science, Technology, Engineering, and Mathematics) to STEAM (Science, Technology, Engineering, *Arts*, and Mathematics). While there is much talk in both Arts education (visual and performing) and STEM education about the possibilities of and for STEAM (cf. Robelen, 2011; "STEM to STEAM"), empirical research on this topic is just now beginning to emerge (e.g., Clark & Button, 2011). For example, many online sources on the topic tend to point to one another, to the ongoing Rhode Island School of Design, National Science Foundation sponsored study ("STEM to STEAM"), or to neuro-scientific studies about the possibilities for STEAM education. As one such executive summary noted,

> Educators are largely unaware of new scientific research; scientists typically do not conduct research with educators in mind as end users; and advocates are convinced of the efficacy of arts integration but need hard evidence to promote it. Communication among these constituencies is almost nonexistent; when information is shared it often is synthesized into headlines or neuro-myth. Ongoing discussion and collaboration has yet to evolve. (Haridman, Magasmen, McKahn, & Eilber, 2009)

Additionally, while there is a growing body of qualitative research that suggests that the visual and performing arts might contribute to STEM learning as we present below, our work represents some of the few studies that explore the possibilities for music both as an educational tool in classrooms and a means for scientists to communicate their ideas to others outside of their respective scientific communities. We therefore see this article as part of a growing number of empirically based discussions of the possible benefits of STEAM-as-music in action (e.g., Emdin, 2009). Furthermore, where the majority of discussions at the intersection of STEM and the arts tend to address how the visual and performing arts can be used to better understand science, we see the arts as a means for conceptualizing, understanding, and expressing science—what science can learn from a performing art rather than what a performing art can help us better understand about science.

On the other hand, we argue that music and musical experience cultivates a particular kind of ontology, a complex combination of being lost in the moment and utterly present, an experience that lies at the heart of IBSE. As Massumi (2002) notes, such experiences are ontogenic, ever-emergent moments of ontology that lead not only to other experiences of being but also to experiences of knowing, what Walter calls the epistemogenic (2013b;

2013c). The difficulty is that liminal and affective experiences are often performative in nature and are therefore often hard to express or teach, precisely because of their affectively ontological nature. As we document below, the opportunity for children to experience being present/lost in processes of creation and for scientists to experience their ideas through the embodied visceral sounds that are music hold important implications for IBSE. These findings are significant as they address both possibilities for inquiry that have often been overlooked and gaps in the literature at the intersection of science, music, creativity and inquiry.

In order to document this argument, the remainder of this manuscript has been divided into the following sections. We begin with a brief review of the significance of our work to IBSE. This is followed by a review of the literature about the uses of music for inquiry in non-music education and of inquiry based science education. The review section is followed by a discussion of our respective studies, the methodologies we utilized, and other central contextual information. In the third section we utilize our respective research projects to document the power and possibilities that processes of music-making hold for IBSE. We then draw these understandings together in a discussion section that is followed by a brief conclusion in which we reiterate the central points presented and outline possible future directions at the intersection of music, sound, science, inquiry and education.

## Significance

There is increased attention to P-12 science education in both the European Union and in North America as can be seen in reports from the European Commission (EC, 2007) and comments regarding a recent initiative focusing on improving STEM education by the Association of American Universities (AAU) ("Undergraduate Stem Initiative"), comments that were immediately heralded by the White House (Wienman, Kanter, & Ferrini-Mundy, 2011). Both the EC and AAU reports indicate a decline in young peoples' interest for science studies due in no small part to how schools communicate science. The EC report also argues that current approaches to science education often stifle the natural curiosity primary school pupils possess towards science.

Inquiry is also central to understandings of science and science education, as is evident throughout the entirety of Inquiry and National Science Education document (Olson & Loucks-Horsely, 2000). Consider, for example, the opening statement from the introduction to this document:

> As pointed about in the National Science Education Standards [National Research Council, 1996], students who use inquiry to learn science engage in many of the same activities and thinking processes as scientists who are seeking to expand human knowledge of the natural world. (p. 1)

These ideas are echoed not only in the United States through the new framework for science education which has begun to replace the 1996 National Science Education Standards referenced in the quoted material above, but also resonate with understandings about the significance of inquiry, in its various socioculturally contextualized meanings, incarnations and iterations of science education around the globe (e.g., Abd-El-Khalick et al., 2004). The centrality of IBSE is also explicitly evident in more recent studies of science teaching (e.g. Buck, Latta, & Leslie-Pelecky, 2007; Harris, & Rooks, 2010) but is also front and center in the Common Core Standards in the US (Dana, Burns, & Wolkenhauer, 2013).

The point here is that although multiple questions remain about what inquiry means for P-12 science education, its connection to contemporary science practices, and how inquiry functions in various scientific communities, inquiry remains a central facet of both science education and scientific research. Yet, while there has been scholarship that indicates the possibilities for music and sound for better understanding educational research (e.g. Bauer, 2000; Bresler, 2009) and engendering classroom inquiry (e.g. Hudak, 1999; Stovall, 2006), there are very few studies at the intersection of music and science education in general and those that exist tend to posit the use of a particular genre of music for a targeted population such as Chris Emden's (2009) strong work on the potential for hip-hop in STEM primarily in city schools.

Additionally, music is a disciplined, critically creative process. While inquiry based science education shares this understanding (Minner, Levy, & Century, 2009; DeHaan, 2009), IBSE as it is enacted in classrooms tends to emphasize critically, linear processes and discipline over creativity. This is perhaps not surprising as, in the United States, recent research shows a declining focus on creativity in schools (Bronson & Merryman, 2010). Compounding this downturn in creativity, the focus standards based education has on discreet facts has had the unfortunate and perhaps unintended side effect of curtailing arts programs in school (Melton, 2006). This trend is particularly evident in districts that are labeled as failing, schools that are disproportionately urban in the United States.

It is our argument that increasing creative activity and its underlying message of IBSE through music integration will strengthen students' understanding, perceptions, and experiences of science as a creative discipline. Accepting creativity as a systemic rather than individual process also furthers the realization that an individual's capacity to produce creative output is basically non-existent without a domain in which creativity may be enacted. Similarly, the introduction of specific creative measures into the science classroom can also create a more targeted framework for pupils (and teachers) to more readily grasp characteristics of creativity.

Furthermore, the use of music in IBSE provides an opportunity for students, teachers, and scientists to consider scientific ideas, ideals, and processes from a more holistic perspective, a type of development specified as desirable in modern European policy literature such as the Green Paper (EC, 2010). Because music is deeply tied to the sensory and the emotional, as we document here, whether one is a first grader in a city school or a scientist in a lab, the ability to consider science through music creates multi-sensory, emotional understandings that are often difficult to attain without the arts. The ability to hear ideas with fresh ears is of similar importance—it is one thing to learn about the cycles of the moon and planetary motion and quite another to write a song about those topics that you and your classmates sing for the remainder of the academic year.

Finally, in conversations with science teacher educators and scientists, both groups have conveyed that one of the most difficult aspects of scientific inquiry is how to teach their students, future science teachers and scientists, what it feels like to be lost in inquiry. This is difficult precisely because it is not an epistemological construct but instead is a way of being. As a colleague shared with Walter during a conversation about science and education, this way of being lost in inquiry is important because "it marks the difference between good and truly great thinking about science." Processes of music making are well suited for experiencing this lost/found paradox because they, like all arts, are simultaneously critical and creative in their process yet, unlike some other art forms, are also immediately explicit—one can hear the sounds one makes and, as in the cases we describe here, use now readily available technology to record and playback those musical experiences.

Indeed, creativity, teaching, and learning are all risky endeavors (Gershon, 2012a; Britzman, 1989, 2003; Kumashiro, 2009). Setting the stage for creative possibilities to thrive (in science education's contexts) requires a willingness to think differently about what science can mean and a similar openness to expanding the boundaries of what we consider to be science education. As Torrance (1972) reminds us, "in creative thinking at its best there are strong elements of the emotional, the irrational" (p. 190). In these ways, a teacher's goal should be to facilitate students' conscious employment of emotional, irrational processes in order to better consider and evaluate alternatives solutions. In sum, the ideas and ideals we explore in this article reside at the intersection of multiple areas of scholarship and our arguments for the ways in which the critically creative processes of music making can inform IBSE are significant in that they represent a generally overlooked educational node of possibility, one that can simultaneously improve IBSE and increase interest in science.

## Music, Science, and Inquiry: Critical Creativity and False Binaries

At the surface, our work in this section to make parallel critically creative inquiry processes in music and science. As such, it can be understood as yet another pushing back at the false binary of mind and body, emotion and reason. For, without at least the residue if not the full presence of over four hundred years of a Cartesian split, the lingering false conceptualization of science as an act of reasoning and music as a practice of emotional understandings might well not exist, as is the case in many non-Western sociocultural norms and values (cf. Feld, 1996; Post, 2005). Yet, as Erlmann (2010) argues, there is a deep history of connections between reason and resonance, so much so that modernity scientific and medical inquiry can be understood as inseparable from aurality.

However, in spite of a lack of distinction between mind and body in many non-Western traditions (cf. Geurts, 2002; Howes, 2003; Stoller, 1997) and the line of scientific inquiry in modernity through the sonic that Erlmann draws, there remains a disconnect between music and science in contemporary Western *education*. Although there are recent incarnations pushing at this boundary, this disconnect exists not so much in the scientific study of sound but instead music as a tool for understanding IBSE. For our purposes here, we focus on the gulf between music and science as it pertains to aspects of both that utilize similar vocabulary to different ends (Garoian & Mathews, 1996). While creativity is central to scientific inquiry, it is often bound by the sequential, rule-bound logics of science. Similarly, although music tends to be understood as a process, it is far less often considered a process of inquiry, instead functioning as an articulation of set notions of musical ideas and ideals.

Therefore, demonstrating the ways in which we are using processes of music-making as a means to further scientific inquiry requires a reimagining of making music as an inquiry process and IBSE as an artistically creative process. The remainder of this section is dedicated to the following two tasks, demonstrating the closed nature of IBSE and music education and a review of literature that suggests that a) scientific processes are most innovated when they emphasize creativity and the affective and that b) similar giant steps in music are made when music making is simultaneously an expression of its most critically creative intentions and intentionally utilized as a mode of inquiry.

Much of what is limiting widespread implementation of IBSE today is a lack of relevant teacher education/practice/approach/content/level in some nations and states in the US, external pressures to achieve test results, and the prioritization of prescribed content as well as textbooks which do not support IBSE. For example, there is lack of incentive for the teacher to develop IBSE competencies in some countries (EC PRIMAS Project, 2011). A teacher’s success is often evaluated by the test results of pupils as is the case with the No Child Left Behind Act (2001) in the United States, a policy that is being replaced with another such measure that while less draconian in some key ways continues to conflate teaching, learning, and assessment. While such annual assessments in the United States are trending towards change in response to Common Core Standards in Science, all indications seem to indicate that standardized assessment of science knowledge will continue. As a result of such policies, teachers are often reluctant to take risks and experiment with creating the type of knowledge that, though crucial for the pupil and her society, may not lead to the kind of results a specific evaluation rewards.

Additionally, as increasing numbers of elementary school teachers are sharing with Walter, the pressures to increase success in language arts and mathematics as measured on annual standardized assessments has had the unfortunate side effect of them feeling pressured to spend increasingly less time on science content, in spite of its recent inclusion on such annual assessments. When placed alongside one another, this combination of factors seems to indicate that risk-taking, the ability and daring to improvise, and the willingness to make mistakes and be corrected must be internalized by teachers to some degree before they can transfer these values and goals to pupils (on the importance of practice and internalization of processes, see Britzman, 2003).

Teachers are also faced with the necessity to develop new skills to incorporate constructivist, inquiry-based strategies in music, those that will encourage pupils to construct musical meanings themselves with her guidance rather than immersing themselves in her pre-defined exercises (Scott, 2008). Yet it has been our respective experience as musicians and educators that music education can and often does focus on the mastering of particular skills rather than the developing of artistic sensibilities.

This said, in music education at its best, it is the pupil's or musician's ability to be completely present in the process—to "lose" oneself in the moment—when truly inspiring thoughts, emotions, ideas and performances are generated. The same holds true for idea generation and inquiry in science. However, due to the above-mentioned factors, although inquiry based teaching should be more widespread, its implementation is often hampered. Music education itself may only stand to gain from allowing inquiry-based processes to more deeply infuse the learning process. This will take the music student beyond playing her instrument to a much deeper understanding of the meanings, abstract and others, of what she is playing, of how her mind, emotion, anatomy are collaborating to produce this sound, as well as of the creative processes that had to take place in order for the music she is reading to exist, and perhaps above all, the creativity of improvisation (Bailey, 1993; Lewis, 2008; Oliveros, 2005).

The division of sciences from other creative disciplines such as music is increasingly understood as a leftover Cartesianism that falsely splits mind from body and reifies notions of privileging science over art. Doing so removes a more holistic construction of schooling and students (cf. Cooper, 1892; Dewey, 1929, 1934). It is our perspective that even more creative aspects for science education still tend to focus on rules over inquiry and continue to privilege thought over affect and intuition. While processes of inquiry and frameworks for knowledge and its production are certainly important, it is our contention that scientific discovery and innovation often move in lateral, liminal ways that often have more in common with the arts than they do with common conceptualizations of science. Therefore, we believe that inquiry-based science education should be infused with more creativity and it is to this point that we now turn.

## Music, STEAM, Science and IBSE

There is growing attention to the possibility of adding the Arts to STEM education, driven in no small part by a National Science Foundation supported grant at the Rhode Island School of Design called "Bridging STEM to STEAM (Science, Technology, Engineering, Arts, and Mathematics)" ("STEM to STEAM"). According to the project's website, this is not simply about "fostering innovation through the addition of Art and Design to STEM education and research" but it also "represents the economic progress and breakthrough innovation that comes from adding art and design to STEM" (STEM to STEAM, n.p.).

Although there is focus here on the importance of the Arts, it seems to be primarily on visual arts and media rather than on the performing arts. In contrast, conversations at the intersection of music, science, and education tend to present the important neurological possibilities in learning music for the positive development of the brain (e.g. Jourdain, 1998; Levtin, 2006; Mannes, 2011; Sacks, 2007). Similarly, there is an understanding that music is important in education for both its pedagogical value and in the ways in which music can aid understanding of musical and non-musical ideas for students (for a review of these ideas and studies, see Gershon, 2011c).

However, not only are such studies largely texted but they also tend not to address either the relationship between music and STEM or music and IBSE. Our respective projects also differ from Dr. Christopher Emdin's (2009) work at the intersection of science and the hip-hop generation[2]. Although there is certainly some degree of overlap, where Emdin focuses on connections between hip-hop culture and science, our work examines what processes of music-making mean for inquiry in science education. Additionally, while there are certainly questions of culture addressed in this manuscript, our efforts here relate to processes of inquiry and ways of being that are particularly beneficial for both processes of inquiry in general and inquiry-based science education in specific. In short, although some of the students might use hip-hop as a way of communicating scientific ideas musically, the ways in

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[2] Our point is not that hip hop cannot reach non-urban schools or that Dr. Emdin's work is somehow not applicable outside of city schools. Such a framing would be a misunderstanding of both the power of his work and of music in general. Rather, we are noting that such projects tend to utilize specific musical genres for targeted populations.

which students and musicians get lost in the process of music creation, though in many ways highly independent, shares an ontological commonality associated with deep inquiry and reflection in science.

Consider, for example, the ways in which Feynman (1985) talks about thinking about problems for weeks or how being lost in thought and concentration can look like a person napping or staring off into space. The Root-Bernsteins (1999) similarly describe the importance of creativity and affect in inquiry processes that, at their root, can be conceptualized as the kind of absent/presence we present below, discussions of creativity and process Csikszentmihalyi (1997, 2008) has famously called "flow."

The kinds of inquiry present in processes of music making, the creation of music and, of at least equal importance, the critically creative act of engagement in music can all serve as experiential pathways for better understanding IBSE. This latter point can be understood as a move from an emphasis on ways of knowing to the reassertion that educational experience and inquiry are both instances of ways of knowing and ways of being.

From this perspective, ontological frameworks and the ontogenic are as central to strong IBSE as epistemologies and heuristics. It is here that music, in its ability to express experiences that are difficult to name can aid in both the intention and expression of IBSE. This is because IBSE frames creativity and possibility according to the rules of science rather than openness of artistic creativity. By this we do not mean that fields of science should not operate according to accepted principles and practices but instead that such rules, like all rules, can get in the way of possibilities. The same can hold true in processes of music making and creation. However, because of its location in the arts, the boundaries for creativity tend to be, though certainly not always, more loose than those found in the sciences.

It is also at this point that our lives as musicians who work in science contexts comes to bear. We understand music making as a process of inquiry and IBSE as artistically creative. Our project here, then, is the explication and documentation of this argument, that processes of making music have some significant possibilities for inquiry based science education, a position that is in many ways parallel to Liora Bresler's (2005) discussion of "what musicianship can teach educational research."

## Fields of Inquiry

Processes of inquiry can be conceptualized as loose, fluid frameworks for the exploration of ideas and possibilities. As such, frames for inquiry function more like springboards than static structures and our discussion of them here, though somewhat linear and sequential, need not either function exactly in the manner we describe nor is there a need to adhere to them in the fashion we detail. Of equal importance, while fluid, open frameworks are an integral and necessary part of inquiry processes, the act of framing itself can limit both what is seen and the ways in which those ideas are recognized (see Gershon, 2011c; Handelman, 2001).

Because metaphors strongly inform how ideas and ideals are conceptualized and categorized (e.g. Lakoff & Johnson, 2003; Lakoff, 2004), what might seem to be a semantic difference at its surface is particularly germane to our discussion and understanding of inquiry. Therefore, in lieu of discussions of frameworks, we think about the ingredients for inquiry as fields of understanding, a continuation of Walter's (Gershon, 2013b) previous incarnation of this suggestion. By fields, we mean that the aspects of inquiry we describe are integral but can be assembled in myriad ways towards genuine, authentic questions as well as critically open and creatively involved explorations.

What then might be central aspects within fields of inquiry? With an understanding that there have been different ways of articulating the ideas and ideals we express here and that this list is meant to be exemplary rather than exhaustive, we offer our understandings of the central aspects in strong, authentic, genuine processes of inquiry.

Inquiry tends to begin with an "authentic" question. As opposed to "known information questions" (Mehan, 1979), an authentic question is one to which the person asking does not know the answer. In inquiry based education, this is important not only for the students but also for the teacher. While the teacher may well believe that she has the answer to a question, she must remain open to students' explanations that fall outside of her expectations. This is significant not only because answers that may not at first seem correct according to pre-established constructions of science, a young child's explanation for gravity for example, can help them better understand connections between their experiences and more global scientific understandings, but also because their answers are likely to be plausible. Therefore, encouraging students' wonder about what is possible is likely to lead to explanations that may not jive with contemporary constructions of science but may yet be sensible. Engendering this kind of wonder promotes the very kinds of thinking that scientists utilize when making lateral leaps to discovery (e.g. Feynman, 1997; Root-Bernstein & Root-Bernstein, 1999).

There is a good deal of talk in processes of inquiry about the importance of reflection and rightly so. Without taking time to process the steps one took or to consider alternate paths, one cannot begin to have a grasp of either what transpired or the possibility of replicating particular steps in other processes. We wish to push this one step further, from reflectivity to reflexivity. From our perspective, being reflexive is taking into consideration both multiple iterations of a particular event as well as the sociocultural contexts that inform that reflection. As such, reflexivity is reflection that takes into account sociocultural precepts such as race, class, gender, and sexual orientation as well as local and less local questions of power (Lather, 2007; Willis & Siltanen, 2009). Scientific inquiry is not the same across cultures or nations (e.g. Giessler & Prince, 2009; Varran, 2001) nor should it be—inquiry based learning of any content, science, music or otherwise, should be socio-culturally aware and is necessarily context-dependent (cf. Prime & Miranda, 2006; Weinstein, 2009). Questions about access to ideas or materials as well as the equity with which knowledge is distributed strongly inform what inquiry means and how it can function.

Cataloguing one's experience is similarly important in processes of true inquiry. As meaning in inquiry processes is emergent, what is required is not necessarily a strict plan of action but detailed record keeping of ideas and events as they transpire. This can be done in text, audio, video, picture or other media formats.

Emergence is similarly central to inquiry processes. Authentic questions necessarily lead to new understandings that emerge over the course of a given investigation. As with broader inquiry practices such as research methodologies, a genuine question always produces new knowledge, even when the new knowledge serves to reaffirm existing understandings. Finally, processes of inquiry are always iterative and recursive, they move forward in a repetitive yet additive fashion, doubling back on themselves at each stumbling block only to move forward based on the new knowledge gained in light of that disjuncture.

With these processes in mind, we now turn to our own experiences at the intersections of music and inquiry based science education. For Walter, these questions are presented in relation to a recently concluded longitudinal study of how urban middle grades students use music-making technologies as a curricular tool to write songs about science content.

For Oded, these are musical inspirations and inquiries into how an interpretation of modern scientific developments could sound and read. What is the compositional process that best fits this approach? How should the musicians communicate? Is improvisation the way to go about this, and if so, how much pre-defined structure should be involved? Is using electronics a must to audibly portray the modern thematic material we are dealing with? How to bridge the gap between professional musicians and schools pupils in an educational workshop based on the interpretation of modern science following this approach? How to present the approach to others?

Following Walter's notion of collaborative dissensus (Gershon, 2009, 2010, 2014), we present each of these cases in our own voices, separate sections that include discussions of context, methodology, and findings. We then compare and contrast our two cases in the discussion section that follows our respective presentations of music and IBSE.

**Listening to the Sounds of Science Project (Walter Gershon)**

From fall 2008 through spring 2012, I conducted a collaborative sonic ethnography (Gershon, 2012b, 2013d) that examined how processes of songwriting can function as a curricular tool in science for urban P-8 students. Methodologically, the central difference between sonic ethnography and contemporary ethnographic practices lie in the representation of data as sound (cf. Gershon, 2013d; Feld & Brennis, 2004; Samuels, Meintjes, Ochoa & Porcello, 2010). Here, in addition to following the contemporary tenets of ethnographic research practices that address these questions such as the complex roles of how power and context inform local interactions (e.g. Agar, 1996; Faubian & Marcus, 2009), students and teachers were also active participants in the research process. Residing somewhere between Grant's (1988) use of unnamed high school students as co-anthropologists and Ericksons's discussion of collaborative action ethnography (2006)—a possibility in which teachers but not students were active participants—students wrote songs, recorded audio reflections of their processes, and interviewed one another; teachers also helped gather documents, keep track of students' recordings, and occasionally took photos and videos of students' processes. Students additionally had the option of participating as named participants so that they could get recognition for the work that they did on the project. According to our agreement, because participants elected not to participate in writing this article, their names are used to give them the credit for their work but they are not listed as co-authors.

As I have described elsewhere (Gershon, 2012b, 2013b), this project, originally designed to explore whether processes of music making might help mitigate race and gender gaps in science for city kids, has evolved into a project that teachers and I think of as listening to the sounds of science. The change occurred when we collectively realized that what we were doing was listening not only to students' songs, reflections about their songwriting, and teachers' thoughts about their songs, but also to the sounds of meaning making in science that occurred in each of their classrooms. These sounds included daily lessons about science, students' conversations during science class, and interviews conducted with and by students about the science content they were being exposed to during daily science lessons.

In keeping with our discussion here about the ways in which music can inform and otherwise further notions of creativity and exploration in inquiry-based science education, I have elected to focus on the eighth grade science classroom at Miller South School for the Arts, Akron Public School's visual and performing arts magnet for grades four through eight. There, I worked with Robert "Pat" Marxen, who served as both a seventh and an eighth grade science teacher at Miller South over the course of the study. Pat was in his thirteenth year as a teacher and his six at Miller South at the end of this study in 2012.

Pat often found himself challenged in a manner that is compounded by the context in which he teaches. Where most middle grades teachers have the sometimes unenviable task of creating a classroom context where students are interested in science, a subject that students often convey they have little skill or interest in by the time they reach the eighth grade, Pat's task is complicated by his position as a "core subject" teacher in a school for the arts. How, then, might one interest students in science and the arts?

It is this question that lead Pat to allow me access to the classroom in which he teaches. As Pat shared with me about his thought process in allowing me in the room: "I thought, what might I want if I was an eighth grade kid? When you called me, I thought, this music thing might just be the key."

What began as four donated old eMac computers turned into eight as Pat solicited an additional four computers from connections he had throughout the district and at other universities. In kind donations and grants through the project brought eight pairs of studio-quality headphones, a higher-end USB-enabled microphone, and a MacMini computer to the classroom in third year of this project. To accommodate the growing number of computers and associated audio gear, Pat bought four tables and accompanying stools to form a large computer center at the back of the classroom.

Participating students were asked to write songs about the science content of their choice, record regular audio reflections of their songwriting processes, and video record their reflections and thoughts when they chose. In addition to these requests, I also visited the classroom approximately every two weeks to audio and videotape lessons, observe students' working on their songs, and to interview students and Pat about their experiences. While the songs most often functioned as they were intended, as a means for students to express their knowledge about the academic content they learned during regular classroom lessons, their songwriting processes also often lead to students either returning to previously learned content or looking up additional information about content to include in their songs.

The following is one example of how students worked together to write songs about science. In this instance, the boys began writing based on the ideas they recalled from class, then returned to their class notes and textbook to bolster their rapped arguments about which scientist held a higher claim to discussions of physical science.

Four boys sit behind a row of eMac computers, adjusting their headphones. Three of the boys, Ryan, John, and Jordan are working together on a song that reviews key ideas in Galileo and Newton's theories and pits them against one another in a mock-boxing ring. This metaphor also mirrors the ways in which hip-hop has carried forward contests of musicianship that are endemic in music in the African diaspora.

Unlike many of their friends who compiled the sounds for their songs, wrote the accompanying lyrics, and then sang or rapped their songs, these three boys' process in many ways mirrored those in professional recording studios. As all three boys are at Miller South for music, their unintentional-seeming paralleling of professional recording contexts is perhaps not surprising. In this instance, Ryan acted as the producer for this song, arriving at the idea of how he and his friends might put the song together and creating the sounds his friends would rap on. John and Jordan then wrote their own lyrics to fit within the "beat" that Ryan created. All three boys commented on each other's work in ways that were consistent with being good friends in the eighth grade, from thoughtful advice to teasing, yet I have no record of any of the three being truly upset or yelling at one another in the creation of this song. This too mirrors my and Oded's experiences as recording musicians. Different studios have different ways of being professional and when good friends record, it is often the case that the music making can be understood as a form of serious play (Lindquist & Handelman, 2001), or what Ortner (1996) calls "serious games," and the in-between music moments are a release from that intensity.

As Ryan describes in his two audio reflections about the creation of their song, The Main Event, he arrived at the concept for the song after a lesson in which "we learned about how Issac Newton used Gallileo's theories to make up all of his theories." In Ryan's mind he "thought that if he was still alive, Gallileo would be kinda mad. So I thought it'd be pretty cool if they had a boxing match against each other so that's what we did." Ryan made a beat to serve as a musical platform then invited his friends John, who played the voice of Gallileo, and Jordan, who voiced Newton's positions, to verbally spar with one another, a back and forth verbal match that is about science achievements, replete with Ryan serving as the announcer, crowd noises, bells between rounds, and just enough swagger for each person to get his character's points across. The following vignette occurred on the day that it occurred to Ryan that, in addition to serving as the announcer for the boxing match, he could also add his voice to a character of a ringside coach, offering advice in the boxer's corner on how to be more successful in the match.

## Vignette

As the boys work at their song, Mr. Marxen continues teaching the class, a lesson on forces of motion and friction. Ryan and John stand side by side, each with one headphone cupped to their ear. I momentarily walk in between John and Jordan at Brian's request to better connect a cable that has been giving the boys and others who use it some difficulty. While I am working on the headphone connections out of the frame, Ryan and John take the set of headphones that Ryan has been using, invert two of the headphone ear cups, then lean their heads together so that they can each hear out of one side of the headphones that Ryan had just been wearing while working on their song.

Ryan clicks the mouse sending the song moving forward as John nods and says, “Yeah.”

“I was trying to stop it,” Ryan says smiling as he clicks the mouse again stopping the track from playback.

“Try this sort of funk back. I just want to hear that,” John asks Ryan pointing at the screen.

Ryan and John then look at the screen, both leaning forward as John points to a different track in the song. Ryan then leans forward to the microphone mounted on the end of a slightly-extended mic stand, holds one finger up to John signaling him to hold his thought for a moment and begins to record.

“Okay, you’re doing good but he keeps getting you with that right hook, you really learn to duck under it, you think you got it,” Ryan records.

“Yeah, I dunno man, he’s fast, but, I’ll hit him with one strong blow and he’s out,” John replies on the recording.

“What are you guys doing?” Jordan asks Ryan and John, leaning around me as I continue to work on the loose connection in the headphone cable.

“Okay. For what this you mean?” John replies.

“In the spaces between our raps,” John continues leaning forward to look around me as he talks with Jordan while I leaned forward to reconnect the headphones, “we’re adding some bits about it like we’re talking to coaches.”

“So I gotta come do this,” Jordan says as he starts to put his headphones down.

“Yeah,” John replies as Jordan moves next to John now that I have walked away from where the boys are working. Jordan stands behind Ryan and John who remain seated on the stools in front of the computer where they are working.

“Let me get this set up here,” Ryan tells John and Jordan.

"So when's my part," Jordan starts to ask when Ryan and John both raise a finger to their lips and say "shh" as they smile in tandem.

Ryan then plays the song for a literal two seconds with the headphones out so that all three boys can hear the song play together. A beat/rhythm track sounds and is followed by the sound of a bell ringing twice at which point Ryan and Jordan's faces light up with huge grins and John laughs.

Jordan then asks the other two boys where the recording went and Ryan informs him that the vocal is below but he and John are going to do another take of their in-between round conversations. Ryan selects the record option then leans back into the microphone.

"Okay, you're doing good but he's still getting you with that right hook, but you really got to learn to duck under it. Other than that, you're doing fine. You think you got it?" Ryan records.

"Yeah, he's fast," John says into the live mic and continues turning to look back over his shoulder, smiling at Jordan as he records, "but one strong blow should knock him out."

"Okay, go out there and get 'im!" Ryan replies into the mic in his role as announcer/coach.

"I think I got this," John replies in the mic before Ryan stops the recording.

John and Ryan then start to listen back to the latest take again sharing Ryan's headphones and all three begin to negotiate the next steps in the recording of the coaching interludes. Here is the final product of the boys' collaboration, a song they titled The Main Event:

In these ways, students in this project engaged in an iterative process of scientific inquiry. First, students used music to critically and creatively consider their ideas about science content. They made decisions about the sounds they wished to hear, reflected on those ideas, checked with others then confirmed those decisions. They then worked independently or collectively to create songs that simultaneously ascribed to their aesthetic sensibilities and their academic content knowledge about science. Formal layers of reflection and recording form the second layer of this inquiry process. Not only were students thinking about their work as they conducted it but they were also reflecting on this process as they moved forward, articulating ideas and processes so they could consider them again in the future. As with the processes that Ryan described in his reflection and emerged through John and Jordan's interactions at the beginning of this section, students decided how they wished to combine the samples, the forms songs could take, and when they were satisfied with the results instrumental, sonic, and vocal alike.

Additionally, students' conversations about the ideas they were considering are reflections of the science content they were learning and the deliberations they had over lyrics were moves to concisely and concretely convey scientific ideas and ideals in ways that were meaningful to the students. This is important because it can serve as a means for understanding what science content students recall and can manipulate, rather than more teacher-driven assessments.

What sets this process apart from other forms of scientific inquiry, and resonates with Oded's descriptions of music creation with scientists, is an openness to possibility in inquiry through creative processes. As we argue in the following section, what musical inquiry can teach processes of scientific inquiry is this kind of fluid, unbounded creativity, the kinds of openness to possibility that are often reserved only for the very youngest exploring science and the higher echelons of particularly theoretical scientific fields such as physics.

## The Science Carnival; (TSC), A Music Ensemble Inspired by Modern Science (Oded Ben-Horin)

The Science Carnival (TSC) is a project that emerged organically in response to several questions about the possibilities for music as an educational tool to convey cutting edge science to non-scientist audiences. These open-ended questions, ones in which I remain interested, include such questions as: can music be used as an educational tool outside of institutional settings such as schools; how would scientists interact with musicians; how would other scientists react to the scientific ideas and ideals they heard; what would audiences think about songs with lyrical content specifically about science; what kinds of spaces and places might welcome such work; and would the resulting music have the necessary integrity for both musical and scientific communities?

Working chronologically, I focus here on the ways in which TSC developed in the first few years of its inception. This includes a discussion of my first attempts at connecting science and music, the case of "Mr. Blue Genes," the song that in many ways remains a blueprint for how science, music, and performance interconnect in TSC, and other early examples of my approach. Along the way, I also detail how specific live events were designed in order to demonstrate how science, compositions, and their performance are interrelated in order to illustrate how TSC is both a group and an emergent collaborative process, concluding with an update on how TSC has functioned in the past ten years and recent connections to P-12 education.

To date, TSC has primarily focused on composition, text writing, recordings and performances, as well as the early phases of documenting these processes for a research project based on this still-emerging possibility at the intersection of science, music, and education. Borrowing from long standing approaches to developing musical compositions, stories, and poetry, the musical representation of these scientific ideas involved first interpreting these understandings as poems then performing the poetry as lyrics contextualized by different instrumentations and in various musical settings such as small clubs and rehearsal spaces.

Methodologically, as with all musics and forms of qualitative research, texts in TSC are not meant to be objective but are instead explicitly interpretations of ideas and ideals (Faubian& Marcus, 2009; Lewis, 2008; Sterne, 2003). This is doubly so here as I not only interpreted scientific ideas but also translated them again as music. The process also created a kind of similarly-doubled artistic perspective, one in which I was invested as a musician and another in which I participated as researcher, processes that were never truly distinct and became fully enmeshed as interpretation of research data became songs conveyed to others. This qualitative approach is most similar to a naturalistic approach to inquiry (Lincoln & Guba, 1985) and aspects of strong autoethnography such as the work of Ruth Behar (1997, 2009) in which the researcher's presence, interactions, and processes are deeply imbricated as method.

Finally, it is important to again note that although my narrative here is presented in chronological order and in a relatively linear and sequential fashion, my understandings of this work as inquiry based was emergent and became clear only in reflexively examining my experiences and the resulting data. In point of fact, in the earlier stages of this project I was primarily concerned with the nature of science and scientific ideas and ideals. It was only in retrospect that I began to understand this project as simultaneously defined by and focused upon inquiry processes. These understandings emerged organically, not only in my own retrospection and review of data but also through long discussions with musicians, radio personnel, members of the music industry, and my own experiences in performing science-as-music. However, it was not until I began teaching at an institution that focused on teacher education that I realized the kinds of inquiry in which I had engaged could also provide a foundation for pedagogy.

## TSC: Process in Practice

From 1998-2001, I found myself consistently contemplating several questions related to my life as a musician and vocalist: What message did I convey to others (audience and fellow musicians alike) when I got on stage and took a microphone in my hand? On which basis did I have the right to do that? Did I have a point of view to offer that others did not? Did I have something to offer that would matter to them? In addition, I was searching for a similar answer with regard to the music I was performing. What music do I have to offer a public that has already been exposed to modern day jazz instrumentalists the likes of Joshua Redman and Adrian Pflugshaupt, or vocalists such as Kurt Elling and Lauren Newton?

It was also during this period that I became particularly interested in developments in science and technology. These were phenomena I found myself contemplating in an unending feedback loop literally night and day. At the same time as I was so intensely thinking about developments in science and technology, I was simultaneously wondering about questions that related to my life as a musician: the possibilities for my artistic space as a musician to provide an intellectual message (Gershon, 2010), how I might design a music that was in some way uniquely my own, and the desire to include lyrical content about issues in which I was not only "interested," but in fact those that I came to admit to myself that I was truly passionate about. This simultaneous passion about science and technology and searching for lyrical and musical content that I both believed to be of consequence and was a good fit for the direction I ultimately wished to go as a musician ultimately merged into what has since become TSC.

However, this coming together of scientists, scientific ideas, and music did not happen overnight. My first attempt at this combination was a song about the Internet that was a little rough around the edges at best. Even though the song got some radio play in the country of my birth, I quickly shelved it as I understood this song as a preliminary venture into a new interdisciplinary space that helped me better understand how such a possibility could come to fruition rather than a realization of these possibilities.

The process that has become the framework for how The Science Carnival continues to operate emerged during my second attempt at this collaboration. It begins with a conversation with a scientist. In this case, by the end of 2000, I had begun a series of talks with Dr. S., a microbiologist at the National Institute of Health in the United States. Although the central focus of Dr. S.'s work at the time was research and fund-raising for AIDS vaccinations, our discussions primarily concerned the possible future dangers in human genetic engineering and informatics. From Dr. S.'s perspective, while she saw possible positive outcomes in the field, she felt much more strongly that there were and remain many potential dangers about which the general public was most often unaware. In the course of our conversations, we decided to write a song together in order to communicate Dr. S.'s concerns, ones that I largely share, to a wider audience.

We began with Dr. S. in twin roles as the scientist and teacher, pointing out issues and scientific ideas that could be included in the song's lyrical content and specific cases of discoveries in genetics that had already or could happen in the near future, such as people being unemployable or losing their jobs because they had an unfavorable genetic composition. I then created the poetry that would form the lyrical content for a song based on our conversations.

When completed, I read the poem to her over the phone. Aside from one comment regarding the use of one word that was apparently preferably avoided by NIH microbiologists who are planning to include their name as co-authors in a song (rhymes with "luck"), she agreed with every word and turn of phrase (we went with "heck").

The lyric-writing part complete, I then composed music that I thought fit the lyric/poem's tone, tenor, and content, assembled a band of flexible jazz musicians—players with a particular combination of skill, depth and creativity that allowed me to get the most of recording time in a studio and the kind of musical response I sought—and then booked a studio and recorded the song. Just in time. Dr. S. passed away just weeks after hearing the final version of the song.

Dr. S.'s colleagues at the NIH received the song with mixed emotions. On one hand, they appreciated that science served as content for a song, and, after her passing, the song was a bittersweet reminder of their friend and colleague. On the other hand, several of her colleagues believed the ideas to be too skeptical of genetic developments. However, Dr. S. was well aware of her colleagues' thoughts and positions and was unfazed by this aspect of their responses. I too was pleased, both with the method we had used and the artistic product. I was also aware that her views represented one end of the spectrum of possibilities and though they leaned in that direction they were not unrealistic; time will tell.

<u>Mr. Blue Genes</u>
Don't tell him that I told you
He is sensitive and mean
I would never be forgiven
If he knew I spilled the beans

Please don't tell him that I told you
Genetic rumours killed his dreams
But if you're wondering what The New Discrimination means, get a hold of this story:

Mr. Blue Genes! You’re waking up to what The New Discrimination means!

“Genetic profiling” screamed the headlines in the Times
Just another story unless you are reading through the lines
Lines of unemployed people who appear to look just fine
Up until you read their genes

Please! Don’t tell them that we told you
Genetic rumours killed their dreams
But if you are wondering what The New Informatics means, get a hold of this story

Mr. Blue Genes! You’re waking up to what The New Discrimination means
Mr. Blue Genes, blue genes, you’re waking up to what The New Discrimination means

Watch out! You might think you’ve got it made
But it’s a new millenium, new games to be played
Let’s see if your genetics fit the qualifications of the trade
Let’s see what genes you wear...

Oh...applying for medical care? Hey, we’re gonna have to check you out
Hey! I just wanna see a doctor! What the heck’s this all about?
Don’t you know? The New Society is throwing the genetically deprived out?
Let’s see what genes you wear...

Another breakthrough? Great! But what roles do we play?
Where does it go from here? What price could we pay?
Are we really in control? Or are we headed for a black genetic hole?
Heaven help us and the genetics of our souls

In true inquiry fashion, upon reflecting about this process once the song had been around for some weeks, I came to another realization: This could be a system, a way of doing things, a project, even a band.

Over time and some years later, as I further considered what it was I had done, this process appeared to have many of the hallmarks of inquiry based science education (Minner, Levy & Century, 2009). For example, I had begun with open ended questions that were pursued through a combination of research, conversations with experts, and more affectively intuitive lateral thought; the content was enunciated connections between science, scientific processes, and broader sociocultural contexts; the focus was on a particular set of scientific questions as it related to a specific scientific field, I had a high level of ownership of the disseminated knowledge and I had taken responsibility for my own learning, making the necessary decisions and choices throughout the process in an individually responsible yet collaborative fashion.

My next composition was dedicated to wildlife preservation and marks another possible pathway for collaboration between science and musical communities. For this project, as Dr. S. suggested shortly before she passed, I worked without doing research on my own rather than with a scientist and the song focused on questions pertaining to wildlife. In this process, my work here was more that of a "traditional" scholar and researcher: I explored questions of wildlife preservation in scholarly more popular journals, watched documentaries on the subject and the like. The song, "I'd Go To Jail For A Whale," was a simple spoken word composition with a middle section that introduced a two-voiced section for oboe and mezzosoprano that included a harmony change intended to symbolize the subject's depth and beauty. However, the instrumentation for the drums was not traditional; a computer musician programmed whale-like sounds to perform the role of a drummer.

It was also around this time that I became acquainted with Dr. R. S., a scholar whose work addresses science, the arts, and the borderline between them, a combination for which he has gained national recognition from the European nation in which he works. After hearing about my work, Dr. R. S. decided to involve music I would create in the conference he hosts. For this performance he requested that I utilize a relatively unusual ensemble of only a drummer and myself (vocals) and that the compositions address notions of consciousness, the topic of the 2001 conference. This combination produced two poems about consciousness in the cyber-age that were accompanied only by rhythms.
At this stage in TSC's development, it was increasingly clear that what began as a set of questions about the intersection of science and music was well on its way to becoming a musical project, replete with a traditional "band" of musicians. It was also similarly clear that if I wanted to systematically share my perspectives and interpretations of science musically, I would have to further engage in processes of more formal data collection, how that data would be represented in and through music, and more deeply consider the ways in which the resulting music about science could be communicated to audiences for whom this may be a relatively novel idea.

Fast forwarding to 2011, TSC has produced two CDs inspired by science. The latest was written in collaboration with an international marine research project studying life at a major maritime research center led by a museum and a national foundation for marine research. To date, TSC has performed extensively in Europe and the United States in music clubs, science conventions, research and education conferences, and the like. Seeing the musical progression as a scientific inquiry process and allowing the scientific knowledge gathering to be emotionally infused has been a wonderful journey that is just now starting to reach its full potential. At the same time, TSC has now begun to develop activities in the fields of cross-disciplinary and IBSE education. Initial forays into such possibilities in the past two years have included working with 9$^{th}$ graders on composing music and dance based on ideas in their physics notebook, inviting music teacher training students to compose science-inspired songs for 6$^{th}$ graders, as well as the production of science-inspired school operas with teenagers. TSC continues to performatively enunciate the central tenets of IBSE through a focus on research, open ended questions, problem based learning, collaborative products that are iteratively recursive, returning on themselves in process while generating new questions and products at each revolution. It is my hope that these beginnings, as well as those of many other artists, scientists, education researchers and educators, will provide the basis for future developments in a field that blurs the boundaries between science, music, and inquiry based science education.

## Lost and Found: Being and Presence in Processes of Making Music

What is missing from our discussion above is the importance of how processes of making music impact students in embodied, affective ways. Specifically, we seek here to outline the centrality of aspects of inquiry that are most often overlooked or disregarded, what we have come to think of as the "is-ness" of music-making and inquiry. Discussions about being simultaneously lost and found, of letting go and being present, are plentiful in discussions of musical expression (e.g. Bailey, 1993; Crafts, Cavicci, Keil & the Music in Daily Life Project; Feld, 1982; Lewis, 2008; Oliveros, 2005). While indebted to conversations about the body and embodiment in and through music (e.g. Dunn & Jones, 1994; Magrini, 2003), our discussion here is closest to arguments made by scholars such as Friedson (2009) who posits that drumming is an embodied ontology (pp. 143-144), Erlmann's (2010) discussion of sound ways of knowing and being, and Feld's ongoing argument for the entangled web of being, meaning and sound (1996, 2000, 2012).

Our focus here is on the experience of being in, with, and through music. As we present here, how something is felt, the ways in which sound impacts a body, and the resonance of ideas are all central to our point. This can be understood as an examination of those aspects of musical experience that are the most difficult to nail down, affect, sensual, ontological moments, experiences that can supersede meanings or can be meaningful yet difficult to articulate linguistically. Art is indeed often the expression of intentions, affects, possibilities which we cannot otherwise articulate, and music is no exception.

What differentiates our discussion of this use of music is in the connections we are making to processes of inquiry in general. It is the need to be lost in and present with music in its creation, moments that are temporal, liminal, and significant, that also lies at the heart of scientific inquiry. A willingness to give in to wonder and possibility, a proactive, enacted lost-ness in search of emergent possibilities that tend to emerge before they are known, similar to Feynman's imagining of a formula as a growing object or Einstein's similarly imaginative consideration of what it might mean to be an atom (Root-Bernstein & Root-Bernstein, 1999).

For Ryan, John, and Jordan, their embodiment was visceral and observable. As Ryan began to record as the "coach" encouraging John-cum-Gallileo to watch out for Newton's onslaught of punches, he leaned into the microphone. His eyes brightened as he started to speak. John, headphones held to one ear, smiled and responded in time, leaning into the single microphone as Ryan leaned back, the smile as audible on the first take as it is visible. So lost in the moment are the two boys that they were not only ignoring me as I talked through difficulties with the microphone with a peer, they had similarly tuned out Jordan who now stood on the other side of my body from the two boys with whom he had been working just moments before.

Jordan, on the other hand, had not lost track of his friends as they recorded. He was looking over and around my body, trying to get a look at them. Once he caught John's attention, John leaned under my arm and explained what he and Ryan had been working on while Jordan was stuck on the other side of me. As I moved to leave, Jordan, who was excited to be with both boys started talking, at which point both of his friends, simultaneously, raise their fingers to hush Jordan so that he does not interrupt their second take that was currently in progress.

One moment, John and Ryan, two eighth grade boys, were leaning next to each other, heads practically pressed together listening intently, literally shoulder to shoulder, smiling. Neither boy was uncomfortable with their closeness, nor were they particularly attending to it. Instead they were focused on the sounds coming through the headphones, nodding to the beat, smiling. Jordan stood behind them with the other pair of headphones, staring at the screen, moving his head slightly in time. The headphone jack got unplugged and, as they realized it was out, all three boys put down their headphones without looking at each other, almost as if it was a previously agreed upon synchronicity.

As the section ends, Ryan and John turn around with huge grins to look at Jordan who greets them similarly.

"Okay, let me get in there," Jordan said moving forward towards the microphone on the stand as the other two boys made room for him to begin his repartee in his role as Isaac Newton with Ryan as his coach, talking him through the fight as he did with John.

The boys were present/lost in music. Thinking about ideas, listening, being. When I talked to them later about their experiences in working on their song that day, they focused on the ideas they worked on, discussions that paralleled Ryan's audio reflection about his process on the song.

How did you feel about the songs? I asked them as they were getting ready to leave the class. Here these three loquacious kids were at a loss for words. "Fun" John offered; "it was cool, I liked it" Jordan said; and Ryan just nodded and said, "Yeah, um, good." Their answers when I asked them how they knew when they got the take right were similar. "We just know," Ryan responded and John and Jordan agreed.

Yet all three boys agreed that their engagement in science was different when they wrote songs about their experiences. This was not only a question of greater enjoyment. As John told me one day when we were talking about one of his recording sessions, "It's just so much cooler to think about science with music. I'm just more in it."

Here it is important to note that John's comment was not that he was more into music but that he was more in science, but that there was more "there," there. Although not exactly presented in this way, this is a point several students in Mr. Marxen's classes shared with me. For example, Rhuna said that, "I really get into doing the music and sometimes I forget where I am, not that I forget that I'm in school, and I know I'm doing science, but, well, I just forget." Similarly, Kendal shared that she, "just likes to get lost in the music when I'm back there [recording at the computer]."

Students' ways of being as they worked on their songs was and remained noticeably and viscerally different from the majority of their peers' who continued to participate in daily classroom lessons while they recorded. This is not to say that students were not engaged in Mr. Marxen's class or that they did not have room to express themselves for they certainly did. Rather, the point is that even in a strong science teaching, students are much more present, engaged, and otherwise lost in the processes of science through music. So clear is this difference that a doctoral student who helped me one semester commented during a break on her first day in the class, "they're really into it, aren't they? When you told me about this, I had my doubts, I mean they're seventh and eighth graders, but, wow, are they engaged!" (Fieldnotes, January 11, 2011).

Students' talk about their experience resonated with my own experiences in music making. Recent examples in my own musical life include the following two examples. The first is a memory of feeling frustrated with the difficulty I was having getting a relatively simple horn line down only to realize that I had been recording for nearly six hours without a break and needed to eat (not surprisingly getting the take in a single shot after having a brief break and a bite). The second example that comes to mind is another recent experience when I sat down to do some fine-tuning for a composition I was creating for dancers. At one point in the process, I realized that I might like to add a few touches. Looking up at the clock on my computer I saw that it was then nearly three in the morning and that I had been working straight since eight thirty in the evening. Lost in the moment, yet utterly present.

Because the Oded's work has in many ways become a form of autoethnography (Ben-Horin, 2010) and in the spirit of collaboration that we believe resonates both in our respective projects and in our work together, we decided that we would conduct a 20-minute (auto)ethnographic interview (Spradley, 1979) with one another. This also provided us an opportunity to reconsider anew something that had become second nature to us both, the is-ness of performance. Reviewing the transcript of the conversation separately we both agreed that the following strip was most germane to our discussion here.

Gershon: What does it feel like to be lost and found? To be utterly lost in process and completely present in the moment as an artist?

Ben-Horin: It's the joy and excitement of reaching for something.

Gershon: In what way?

Ben-Horin: Well, there are three ways I think of it: writing a lyric, improvising on stage, and writing a composition. I don't know, but I see them as separate things. Which one do you want to know about?

Gershon: It's up to you.

Ben-Horin: Ok. Performing. When I allow myself to be surprised or experience that I am being continually surprised in the moment, I realize that I'm not afraid of taking risks and realize that I will make mistakes as part of the process and I accept those risks. I welcome them because without mistakes there is no way to be in the moment, in a social situation or jazz scat solo. Maybe "mistakes" isn't right, maybe it's "new ideas" that fit into my overall scheme [schema/framework]. At that moment I know I'm creative, I feel beyond a doubt that

I'm creative. At that moment I'm proud of my creativity and I'm proud of presenting my creativity to others.

As Oded notes here, it is this kind of critically creative pride in taking risks, the openness to the moment, and the acceptance of the unanticipated and unexpected, that "mistakes" may in fact be previously unconsidered possibilities. It is this ontological orientation, of embodied being-ness, that can be as positive and productive in doing science as it is in doing music, and ways in which music can perhaps serve as a tool for deepening scientific inquiry.

## Conclusion

The kinds of processes of music making we have described here can be understood to have the following two implications for inquiry-based science education. First, IBSE and making music are both critical and creative activities. These forms of inquiry are both to some degree rule-bound, science to various constructions of scientific inquiry and processes of research and music to understandings of genre, form, emotion and expression. Both scientific inquiry and music making are sociocultural constructions, what counts as science or music is determined by interlaced layers of norms, values, meanings, and codes for interaction (e.g. Turino, 2008; Varran, 2001). There remains, however, an important difference between musical and scientific inquiry. As we have argued here, although it can be present in scientific inquiry, musical inquiry tends to more immediately engage participants in deeply aesthetic and affective ways.

This leads us to our second and perhaps even more important point. Involvement in music making is a means for people to be simultaneously lost and present in the affective liminal simultaneity that is sound/feelings/ideas. What we are arguing is that not only processes of art-making, in this case music, but also scientific and mathematical processes are aesthetic experiences in which the senses are operating at their peak and one is fully present in the lived moment, resonating with the excitement of the experience when one is "fully alive" (Dewey, 1929; Robinson, 2010). Indeed, creativity does not happen in a vacuum. It must take place in a domain of some sort, and can be understood as an action which changes the domain in which it takes place. These usually occur when previously unrelated material is connected. Such discussions of flow and sound as embodied meanings (Baley, 1993; Feld, 1982; Lewis, 2008; Oliveros, 2005) are by no means new.

However, what we are suggesting here represents what may be a new possibility for music's relationship to IBSE. As one friend, physicist, and chair of the math education program at a university in the northeast recently shared with me, "what I can't seem to teach these kids is how to do that, to be lost in the moment, in the idea. It's giving in to that wholly that makes the difference between a really smart person and a great scientist." It is here that musical inquiry has something to offer science education. Music making is often a relatively immediate, visceral experience in giving in to the moment, of being in inquiry.

Creating science-inspired music (and music-inspired science), whether writing songs as we have done or expressing scientific ideas more generally through sound, has strong implications for teaching IBSE on at least the following two fronts. On one hand, not only does songwriting follow many of the steps of IBSE—it poses questions, considers possibilities, engages the music-maker in reflective practice—but writing songs about science also provides students with a less traditional means for reconsidering and reflecting on academic content about science. By writing songs about science, students are both engaging in processes of inquiry and the consideration of ideas about science are the focus of that reflection.

On the other hand, when students become lost in the processes of writing songs about science, they are experiencing the very kinds of openness to possibility that IBSE is designed to encourage. Of equal importance, when the lyrical or other content is focused on scientific ideas and constructs, when students do experience that lost/presence that is often endemic to music creation, they are simultaneously engaging scientific content. In this way, writing songs about science provides the means for students to experience the flow of inquiry and to do so when considering science.

What, then, are potential next steps in our respective work and possible collaborations? What might happen if processes of making music were intentionally utilized as a means for P-12 students to engage in the is-ness of scientific inquiry? Could scientists become more creative and open in their own inquiry if they engaged in processes of music making? What could result in meetings between scientists and students, what kind of music might they make together or about one another?

And where does the limit lie? If currently most people perceive science and the arts as two separate disciplines which some are attempting to bring together, how far can this go? Can we truly envision a school in which science and music are taught as common areas of the same subject? What would that subject be called? Creativity? What would the results look like? How would children growing up in such a school think of science?

With regard to writing songs about science, also here, we must realize that there are many levels on which this can be done. Surely writing a song in a standard 3 minute Verse-Refrain-Verse-Refrain-Bridge-Refrain-Refrain or any other well-established form is marvelous inquiry-based work. But can we challenge our children to write a song structure shaped as a molecule? To write a lyric which sounds like a certain wildlife species? To convey underlying scientific ideas with their music? What would the resulting music look like and how would it be captured graphically? How would such music sound? Would such work allow both educators and scientists to better conceptualize the creative impulse in science and music? It is questions such as these that our respective work begins to address as we move forward working with students in schools and scientists in the field, further enunciating and documenting connections between music and science, the significance the ontogenic, and the potential benefits in moving from STEM to STEAM for inquiry based science education.

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