BioMusic in the Classroom: Interdisciplinary Elementary Science and Music Curriculum Development

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Abstract:

Policymakers and industry leaders are calling for a 21st century education that is more interdisciplinary in nature, including the ability to solve problems and think creatively (PTCS, 2004). Traditional teaching practices that present subjects as separate and distinct disciplines do not encourage students to make connections between subjects in school and in the inherently interdisciplinary nature of their daily lives. It is important for educators to help students link multiple subjects with the world outside the classroom (Katz & McGinnis, 1999), encouraging reform that implements a multidisciplinary approach and real world applications. Boix Mansilla, Miller, and Gardner (2000) describe interdisciplinary learning as integrating concepts from two or more disciplines to establish an understanding that moves beyond the scope of one discipline. It follows that rich inquiry is often achieved by taking multiple perspectives and multiple approaches to examining a science topic (AAAS, 2006).

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Article:

Policymakers and industry leaders are calling for a 21st century education that is more interdisciplinary in nature, including the ability to solve problems and think creatively (PTCS, 2004). Traditional teaching practices that present subjects as separate and distinct disciplines do not encourage students to make connections between subjects in school and in the inherently interdisciplinary nature of their daily lives. It is important for educators to help students link multiple subjects with the world outside the classroom (Katz & McGinnis, 1999), encouraging reform that implements a multidisciplinary approach and real world applications. Boix Mansilla, Miller, and Gardner (2000) describe interdisciplinary learning as integrating concepts from two or more disciplines to establish an understanding that moves beyond the scope of one discipline. It follows that rich inquiry is often achieved by taking multiple perspectives and multiple approaches to examining a science topic (AAAS, 2006).

The goal of transitioning emerging research and development into a classroom-ready form requires collaboration between scientists, researchers, and teachers. As a member of Partnership for 21st Century Skills, the North Carolina Department of Public Instruction has defined goals for helping students become “future ready” (NC Framework for Change, 2008). This term refers to preparing students to think creatively and solve problems, which are targeted by the Partnership for 21st Century Skills (PTCS, 2004) and other policy organizations as essential to life and work in contemporary society. It follows that there is recognition of the need to shift pedagogical approaches beyond simply preparing students either to become future scientists or to pass standardized tests (Millar & Osborne, 1998) and move toward developing scientific literacy among all students (AAAS, 2006). Innovative curriculum, especially when it encourages productive interdisciplinary experiences (Barab & Landa, 1997; Brandt, 1991), can engage students in ways that help them see science directly connected to their daily lives.

With these goals in mind it is important to recognize that students' lives are not divided into discipline areas, yet disciplines are traditionally presented separately in school. Efforts to include true interdisciplinary experiences in today's schools face many obstacles: teachers as subject specialists, class time schedules, traditional school structures limiting teacher time for curriculum development or collaboration, and lack of understanding of interdisciplinary learning (King & Wiseman, 2001). Rather than true interdisciplinary experiences, students usually participate instead in thematic or multidisciplinary approaches. In a case study that explored an interdisciplinary approach to history and visual arts, Dawes and Boix Mansilla (2007) described how interdisciplinary instruction should integrate domains, creating a new understanding. The typical structure of a school day hinders these natural connections and discourages blending concepts. In elementary schools, where there is potential for flexibility in scheduling, teachers still most often divide their instruction of subjects into separate time slots. When teachers specialize in a particular field, they may hesitate to expand from the comfort zone of their field of specialization. Crow and Ponder (2000) suggest restructuring teacher involvement in multiple disciplines by promoting teacher teams—bringing together teachers with different areas of specialization and exposing one another to new content knowledge and instructional approaches.

The present article describes a study that examined the experiences of a teacher team: two elementary school teachers, a music teacher and a science teacher, as they developed and implemented innovative, interdisciplinary curriculum based around BioMusic. This emerging field of research combines physical and biological sciences of sound and animal communication with concepts from the discipline of music. Through BioMusic, this project involved designing curricula to provide opportunities for elementary school students to gain a deeper understanding of their world, expanding beyond the traditional classroom presentation of music and the physical properties of sound. Authentic interdisciplinary connections link value to content (Barab & Landa, 1997; Brown, Collins, & Duguid, 1989), in this case through science and music relationships. The approach taken by this project to develop interdisciplinary curricula encountered the challenges of interdisciplinary work and points to strategies that can nurture and support the important goal of interdisciplinary practice by teachers and experiences by students.

Background for the Study

Science Instruction

There are many challenges in science education, especially at the elementary school level. Marx and Harris (2006) recognized the role of NCLB in developing the culture of standardized tests, which ultimately limited science time and impeded implementation of project-based science curricula. Important efforts in maintaining our nation's leadership in science and technology should begin in elementary school (Bybee, 2007). The National Science Foundation has called for diversifying the pool of talented students entering the STEM pipeline as well as cultivating students' capacity for interdisciplinary exploration (Langen & Dekkers, 2005). Interdisciplinary approaches for including science in elementary school classrooms and maintaining the natural connections between science and other subject areas, including music, can address some of these challenges. It is also important for students to have a broad range of science thinking skills, including work with multimodal data sources. For example, students should have experience with auditory information and re-representing it using, for example, physical models, drawings, words, and musical notations (Barrett, 1997; Britsch, 2009; Harrison & Treagust, 1998; Shepardson & Britsch, 2001; Minogue, Wiebe, Madden, Bedward, & Carter, 2010).

Music Instruction

The National Association for Music Education promotes curriculum design in grades K-12 that helps students understand connections between music and other disciplines (Music Educators National Conference, 1994), but these connections are often superficial and consist of using the repetition of songs to help students memorize facts (Wiggins, 2001). Further, Wiggins warns that integration of music with other disciplines needs to consider the integrity of each of the disciplines in order to be conducted wisely.

Music instruction at the elementary school level includes helping students learn about melody, rhythm, timbre, and harmony, along with finding patterns and tones. Unfortunately, music is often taught in isolation from other disciplines. In a similar vein, content from physical and life sciences have traditionally been taught separately at the elementary school level, yet the natural connections between the physics of sound and the sounds in nature link these two areas of science and science with music.

Interdisciplinary Connections of Science and Music

Interdisciplinary connections were initially promoted as a model for educating children with special needs, however the interdisciplinary approach has become recognized as effective with all students (Welch, et al., 1992). Many school districts in North America support interdisciplinary curricula to address the cognitive, cultural, developmental, motivational, and stylistic diversities of students (Barab & Landa, 1997). Howard Gardner's (1983) work on multiple intelligences offers further support for instructional approaches designed to meet the needs of students who possess various strengths and challenges. Every classroom has students with a wide variety of ability levels and preferred learning modalities whose learning is enhanced when teachers illustrate natural, multimodal connections among concepts.

Applebee, Burroughs, and Cruz (2000) identify a continuum of possibilities when teachers move from traditional, discipline-based instruction to either integrated or interdisciplinary approaches. These range from specialist teachers serving the same group of students but maintaining their independent curricula to teams planning together to create totally new curricular domain, expanding the contributing subject areas, such as BioMusic.

This expansion of subjects aligns with the National Science Teachers Association goals that promote new, creative approaches to curriculum integration with engaging application to students' lives. For example, the two disciplines of science and music can be connected in schools when teaching about sound. Science curriculum often focuses on the physics of sound including the source of sound, the path of sound, the medium through which sound travels, and how sound is received by humans. Music curriculum typically focuses on the quality of various sounds along with traditional Western instruments and songs. Recent research in the biological connections of music and science (Gray, et al., 2001) provide new opportunities for student learning.

BioMusic and UBEATS

Interdisciplinary teaching and learning are promoted to meet the increasing demand for interdisciplinary reasoning in the 21st century (Boix Mansilla, 2010). Interdisciplinary experiences for teachers and for students are, as outlined above, important in elementary education. However, creating curricula through this process can be a challenging proposition. Inevitably, this process involves give and take among its participants and an evolving understanding and appreciation for other theoretical, professional practice, and disciplinary lens on the topics and activities being developed. The Universal BioMusic Achievement Tier in Science (UBEATS) project attempted an interdisciplinary curriculum development project, understanding the challenges that would need to be overcome.

Underlying the UBEATS project is BioMusic, an emerging field of interdisciplinary research that explores the commonalities of musical sounds and time found among species and explores the deep structures and relationships of pitch, phrasing, rhythm, and volume that affect species' roles in biodiversity (Gray, et al., 2001). In addition to humans, some other species studied include whales, birds, mice, and elephants, among others. The interests of BioMusic researchers are varied and span both an interdisciplinary and trans-disciplinary context, including biology, neuroscience, ethnomusicology and bioacoustics.

The UBEATS project is a curriculum development effort designed to promote an awareness of BioMusic concepts for elementary school students. An overarching goal of this project is to enable teachers and their students to explore their aural world as a learning resource for new science and music curriculum based on the standards of both disciplines. This part of the project examines the curriculum development process and pilot testing to expose students to both physical sciences of sound (e.g., animal frequency ranges) and connections of music in the biological world (e.g., bird songs, whale songs). Two teacher partners, an elementary music resource teacher and a science resource teacher, collaborated with the UBEATS science and music education project team leaders. Research scientists working in the emerging field of

BioMusic shared their research during initial training and made themselves available as consultants during the project.

The present project began with an initial introduction to the innovative field of BioMusic, followed by the development of lessons designed to explore the connections of science and music in the natural world. The lessons were pilot-tested with elementary school students in both science and music classrooms. Researchers examined how the interdisciplinary curriculum writing and implementation process impacted a music teacher's and a science teacher's evolving perceptions of hers and her partner's discipline. We explored how the curriculum development process impacted their perception of interdisciplinary instruction, and we focused on the challenges they faced as they became familiar with BioMusic content, wrote lessons, and implemented interdisciplinary instruction. The goal here is to present a study that addresses a void in the research literature on teacher teams at the elementary level and provide additional evidence on interdisciplinary teaching approaches.

Research Questions

The research questions evolved as the process unfolded. Hatch (2002) supports the evolving research question development based on data as it is collected. During this study we sought to investigate the science and music teacher partners' teaming efforts to develop curriculum that presented both the physical sciences of sound and music along with the biological component of music in nature. The research questions for the present project focused on the curriculum writing process of the teachers and their interactions with material from their own discipline and the complementary discipline. Our initial question was, “How do teachers' newly gained knowledge of BioMusic impact teaching and learning in the classrooms of the music and science teachers?” As the study progressed, more focused questions developed. These questions asked:

1. How did the teachers' perceptions of their discipline and their partner's discipline evolve throughout the curriculum writing and implementation process for each teacher?
2. How did the curriculum writing and implementation process impact their image of interdisciplinary instruction?
3. What are some of the challenges of the interdisciplinary curriculum development and implementation process?

Method

A case study method was used to examine the two teachers' curriculum development of this innovative field of research. Yin (2009) supports the case study design for explanatory investigations. Because the two teachers worked closely in the project, they are presented as a team rather than individually. We analyzed data simultaneously with data collection (Hatch, 2002), which guided further observations and interviews for the study. We conducted three interviews with each teacher along with collecting field notes during a total of 19 observations as the teachers piloted the lessons with their students. In addition, we collected copies of both the lesson plans created by the teachers and student work (i.e., student notebooks). Inductive analysis was used to find patterns of themes that emerged from the data (Glasser & Strauss, 1967; Hatch, 2002), which included interviews, field notes, and artifacts (Denzin & Lincoln, 2000). The field notes and interviews were coded to correlate with research questions and identified as relevant in the development or implementation of the interdisciplinary curriculum.

Recruitment of Participants and Setting

The two-person team of teacher partners was recruited to participate in the project through a teacher enhancement fellowship program. Pseudonyms are used for the two teachers in the present case study. Both of the teachers were experienced teachers. “Denise” has been an elementary school teacher for 12 years and for the last four years she has been the science specialist at her school. “Clara” has taught music in various grade levels for 15 years, spending the last 9 years as a music teacher in elementary school. Both of the teachers were drawn to their current school because it is a “creative arts and sciences” magnet school that emphasizes Gardner's multiple intelligences.

Table 1 summarizes the timeline of the project.

Table 1. Project Timeline

Summer 2008	• Research team begin planning meetings • Research team and teachers meet • Teachers and researchers immersed in BioMusic content Presentations by BioMusic scientists • Teacher teams begin initial draft of modules
Fall 2008	• Teachers complete draft of 4/5 module • Research team provides feedback on module • Teachers use feedback and revise 4/5 module • Teachers begin writing 2/3 module
Winter 2008	• Pilot testing of 4/5 modules respectively in 4th grade science and music classes • Mentors observe lessons and collect field notes and artifacts • Teachers collect notes during 4/5 lessons and incorporate them into revisions • Teachers complete 2/3 module draft
Spring 2009	• Pilot testing of 2/3 modules by team teaching in 2nd grade class • Mentors observe lessons and collect field notes and artifacts • Teachers collect notes during 2/3 lessons and incorporate them into revisions • Teachers incorporate their revisions and those of BioMusic scientists and research team in both modules

During the first summer (2008) the two teachers were immersed in multiple training experiences on topics such as guidance in leadership and training in curriculum writing strategies. As part of the UBEATS project, the two teachers spent two weeks learning from researchers who specialize in a wide range of BioMusic fields. Researchers who study bird songs, whale songs, the effect of music on the human brain and body (neuroscience), ethnomusicology, and bioacoustics were among the presenters. Teachers in this project capitalized on connections with the BioMusic researchers who were both scientists and/or musicians, willing to foster cross-disciplinary thinking while providing research materials and connections to field research. We examined the two teachers as they planned the format and guiding questions for their lessons; then they developed the lesson drafts, working both together and individually.

Data Collection and Analysis

Hatch (2002) described qualitative data analyses as a “systematic search for meaning” (p. 48) with the recognition that the researchers engage their own understandings as they attempt to make sense of data. The music and science teachers' curriculum development, revisions, and implementation are described here and are presented as a cross-case analysis (Yin, 2009). The data include interviews, field notes from observations of pilot testing of the lessons, student notebooks and drafts of the lessons themselves.

The initial interviews with the teachers took place at the beginning of the first summer. We conducted a second interview two months later as the teachers began writing the upper elementary learning modules as a team at the start of the school year. The third interview took place at the end of the fall as they completed pilot testing the lessons with their upper elementary school students. During the first interview (see Appendix A) we followed a general interview format (Patton, 1990), but as the interviews progressed we implemented improvisational scripting (LeCompte & Preissle, 1993). The following section is organized by the research questions with related data.

Results

Research Question 1—Evolution of Perspectives on Disciplines

- How did the teachers' perceptions of their discipline and their partner's discipline evolve throughout the curriculum writing and implementation process for each teacher?

During the initial interviews, both teachers described their learning process as they were becoming immersed in interdisciplinary BioMusic concepts. When asked about her comfort teaching science, Denise responded, “I feel comfortable teaching science, but I think the content area for me of BioMusic is the topic that I'm still working toward getting a better understanding of.” Clara described her comfort teaching music, but shared Denise's discomfort in learning to combine science and music in the BioMusic content. Denise explained, “This was an area that was new, and even though we do sound in physical science, connecting it with life science is the different part of it but one that the kids really seem to like.”Anderson et al. (1994) described the complex learning curve that is required when teachers adapt new curricula. Teachers need to connect new material and concepts to their existing understandings. The field of BioMusic is an innovative area of study, requiring teachers and researchers to expand and even reevaluate their existing views of science and music connections.

Regarding their comfort with the complementary field, both expressed a need to learn more about the material. Clara felt unsure about science because she described herself as “not an outdoorsy person” and recognized that she needed to broaden her perspectives to try to see how science and music relate to each other. Denise added:

> “I am definitely learning a lot about music. I actually caught myself thinking sometimes when I hear a sound, how it would look when I'm looking for sonograms for the kids and

> also trying to use the music vocabulary in the lesson. Making those connections with the kids and not coming from a music background, that's a stretch."

Both teachers initially viewed their disciplines through a somewhat traditional lens. Working on the UBEATS project expanded their views: Denise explored sounds in nature, going beyond traditional lessons on vibrations and sound. Carla allowed students to express music using non-traditional notations and identify songs and sound patterns in the natural world, and both teachers learned concepts and vocabulary of BioMusic.

In summary, (1) Each used their existing discipline to bridge into BioMusic: Denise went from physics of sound to biological basis of sound while Clara expanded her view from traditional representation of Western music. (2) Both teachers acknowledged the learning curve required with the complementary field and with the emerging field of BioMusic.

Research Question 2—Interdisciplinary Instruction

- How did the process impact their image of interdisciplinary instruction?

Both teachers were able to elaborate on changes in their images of interdisciplinary instruction, especially relevant coming from a school that focuses on subject area relationships. During the first interview, Clara felt that the curriculum development process with her science partner ". . . brought me insight on similarities between my curriculum and the science field." Denise described her need to learn "all the terms [in music] and where they're found and just the whole color behind music." The importance of learning the complementary terminology, the vocabulary used in their partner's field, was a theme repeated by both teachers during the interviews.

The second interview that took place at the end of the grade 4/5 pilot testing revealed further explorations of the interdisciplinary relationship of music and sound. When we asked Denise how her students would benefit from the interdisciplinary connections, she responded:

> "I know it will help them make connections because when we talk about the science of music and where music is, some students said music is the wind, or music is animals or water dripping and they were talking about just environmental sounds and it was very enlightening."

Field notes regarding interdisciplinary connections described one science class when the students walked around their schoolyard with recording equipment to record the sounds of nature. The following music class built upon this experience. Clara played their recordings for the groups to remind them of their walks, she showed them spectrographs of the sounds, and students drew pictures and words to graphically represent the experience. Embedded in these discussions were music terms of "tempo" and "rhythm" as well as "patterns of vibrations," showing students' interactions with music terms and the science of sound.

Because the teachers developed the lessons together, they were aware of the content in both classes. The shared writing process and paired implementation supported a flow of concepts between classes and both expressed an increased awareness of the other's discipline. Clara felt that she was “certainly thinking more about science now” and she described the students as excited about the connections. She described her impression as coming from a multiple intelligences perspective, saying that the lessons “bring science-centered kids to music and music-centered kids to science.”

Field notes recorded during our observations in Denise's science class described a day when she reminded the students of their work in Clara's class earlier in the week, exploring sounds as vibrations using percussion instruments. Denise had various centers set up to allow students to experience vibrations with wax paper kazoos, tuning forks and their vibrations' impact on salt or water. One student excitedly raised his hand and exclaimed, “I see a connection!” She asked him to explain, and he described the connections between the explorations of vibrations with musical instruments in Clara's class and the recordings of various animal songs during science centers. This incident revealed one student's recognition of a relation between science and music concepts. A neo-Piagetian tradition suggests that an initial understanding of each concept in isolation is necessary before connections between two concepts can be understood (Boix Mansilla, 2010). The developing understanding of science and music concepts and their integration were indicated for the teacher participants as well as the students.

During the pilot testing of the 4/5 modules in the fall, each teacher presented the UBEATS lessons in her own classroom. The lessons were written with the intent that any classroom teacher whether a generalist, music, or science specialist would be comfortable presenting it to his or her students; however, both teachers in the study described greater comfort in teaching their own specialty area. As a result, they decided to teach the 2/3 modules as a team during the pilot testing the following spring. This required coordination from their principal, the classroom teachers, and other specialist teachers, but it was important enough to them to make the arrangements. This effort illustrated the slow transition in their interdisciplinary thinking, especially significant that their comfort zones remained intact even as curriculum developers. It was clear both from the interviews and observations that the two teachers were challenged to expand their visions of the interdisciplinary connections of science and music beyond the physical relationship of science and music to include the biological relationships of sound.

At this point, neither teacher seemed to completely internalize Boix Mansilla, Miller, and Gardner's (2000) definition that interdisciplinary instruction should produce an understanding going beyond the scope of each discipline. Both teachers' knowledge expanded during the process, but they still seemed to maintain their views of “connections” between disciplines rather than developing new understandings beyond their respective disciplines. Yet, by the third interview, both teachers discussed the interdisciplinary concepts of patterns and pitches of animal songs that they used to design inquiry opportunities for students to explore animal behaviors and related song frequencies and rhythms.

In summary, (1) Collaborating as colleagues and teaching a common interdisciplinary curriculum are two different things (the latter is harder). (2) Interdisciplinary work helped drive home commonalities in concepts being taught as well as emphasizing the need to understand the unique connections.

Research Question 3—Challenges of Curriculum Development

- What are some of the challenges of curriculum development and implementation?

Time was identified by each teacher as a challenge, both for the paired writing process and finding time to include the lessons in their existing program. When we asked Clara if she felt confident that the curricular materials would be easily adapted to her school schedule she expressed hesitations. “I do, as long as it's aligned.” We asked her to clarify:

> “My concerns are with the national and state standards . . . so as long as they are aligned I feel like there will be time to include the lessons.”

Denise shared the concerns about whether their lessons met state and national standards:

> “We definitely want it to be based on objectives and that was a little bit tricky too because it fit well with certain state standards so we're looking at ways to adjust the goals to more of the national standards.”

Another challenge was the use of technology to record and illustrate sound images of animal songs, connecting music to biology and physical science. Computers were used to access various animal sounds from the Internet and also to access the BioMusic project's Wild Music website. Various animal songs were translated into spectrograms, showing students a visual representation of the sounds, illustrating patterns and pitch. These graphical representations allowed students to incorporate their visual and aural interpretations of the music in nature, expanding from music and science to the interdisciplinary field of BioMusic.

Field notes included descriptions of various incidents where LCD projectors failed to work, preventing students from viewing the spectrograms along with hearing the recorded sounds. Other times the students could not hear the recorded sounds on the computer because they lacked external speakers. The availability of technology in classrooms has lagged sorely behind the use of technology in much of our society, but with the rapid expansion of technology options, the availability in schools will increase. It is important to prepare students with 21st Century Skills (PTCS, 2004), the multi-dimensional abilities that include information, media, and technology skills.

In addition to technology challenges, structured school schedules discouraged time for teacher collaboration and curriculum development, and both teachers in this study described the time challenge with their interdisciplinary efforts. The pressure to align with standards related to the time constraints with expectations to address standards that may conflict with innovative interdisciplinary approaches. During this study, the teachers' periodic challenges using technology only added to the time pressures and further inhibited instructional efforts to innovatively illustrate the relationships in nature's sounds.

In summary, (1) Time was a challenge in lesson development and implementation. (2) Alignment with standards was a crucial component for teachers to accept the material, and (3) Technology access and implementation challenged the flow of implementation.

Discussion

This case study describes the efforts of two teachers, one music specialist and one science specialist, involved in the UBEATS-BioMusic curriculum development project. The project was designed to promote interdisciplinary connections of music with the physical sciences of sound and the biological relationships of sounds in nature, with an underlying goal of helping students develop science literacy across disciplines. Our research questions focused on the teachers' initial views of their own and their partner's discipline, and we explored their evolving views throughout the curriculum development and implementation process. Another research goal was to identify the challenges they faced throughout the process. The music and science specialists entered the project confident of their field and ability to develop connections; however, they struggled both intellectually and logistically with the connections between their field and with presenting BioMusic as an interdisciplinary concept. The teachers' challenges to meet their goals of interdisciplinary instruction illustrate the difficulties with adapting new curricula.

The UBEATS project is aimed at developing elementary science curricula that will eventually reach classrooms across the nation. Regardless of the excitement of emerging research in science and music, research often does not have a natural flow into the classroom. For teachers, change requires restructuring teachers' beliefs and can be a slow process (Davis, 2002; Tobin, Briscoe & Holman, 1990). Anderson et al., (1994) describe the process for teachers to adapt new curricula as framed in constructivist learning theory, proceeding through an adaptation process that includes active involvement in content and pedagogical construction of meaning. In addition, teachers must connect their new understandings with the learning community. All of this involves adaptation and change of traditional teaching practices, in this case promoting interdisciplinary instruction. As indicated in the first interviews conducted at the start of the first summer, the two teachers entered the project confident in their curriculum development abilities, but as the project developed, their beliefs about their field and that of their partner were challenged as they explored connections in their respective disciplines. Their efforts to fully embrace BioMusic as an interdisciplinary field of its own were expressed in the interviews. Further, even as authors of the curriculum who wrote and implemented the lessons during pilot testing, they struggled with recognition of full interdisciplinary application.

Squire, MaKinster, Barrnett, Luehman, & Barab (2003) suggest that teachers should develop or adapt their own materials rather than inherit university-developed curriculum. The paired recruitment of teachers in the present study allowed the teachers to share the writing process, so they were able to claim ownership of the materials rather than attempt to implement lessons written by others. Maintaining the goal of promoting inquiry opportunities for students, curricula needs to be designed that will be used by teachers in the context of their classrooms.

Researchers in this study found differences in the teachers' approaches toward implementing innovation. During our observations it became apparent that Clara was more resistant to straying from the existing music curriculum and to adopting pedagogical approaches such as the use of science notebooks. Both teachers described their difficulties of learning vocabulary of the their partner's field and of BioMusic concepts. Nikitina and Boix Mansilla (2003) examined integration of mathematics and science in pre-collegiate programs and described specialized knowledge and vocabulary as obstacles to interdisciplinary goals, leading teachers to emphasize singular facts over broad concepts. As teachers change their views of disciplinary instruction they need support in integrating and wielding this new vocabulary and knowledge.

One of the key components necessary to effect change is teacher acceptance of new concepts and strategies. Teachers' beliefs regarding a teacher's role in the classroom, beliefs about how students learn and about the attitudes toward curriculum impact their inclination to implement new curricula. Connelly & Ben-Peretz (1980) conducted a study that documented teachers' need to find its value as necessary before they make the choice to implement the curriculum.

Clara expressed concerns about the new materials fitting into the standards based requirements of the music and science curricula (Byo, 1999), which she felt would indicate that the material would be included in standardized testing. Harlen (1999) recognized that high-stakes testing inevitably impacts what is taught. Implementing reform-minded classroom practices in the atmosphere of school accountability and high-stakes testing face many obstacles. When new science instruction programs are not perceived to match state science education guidelines and correspond to mandated examinations, teachers and administrators may be reluctant to spend time teaching material that does not appear on tests, regardless of their value (Moreno, 1999). The UBEATS team emphasized the importance of this alignment, and review of the final written modules revealed that the lessons included both national and state science and music standards.

Implications

Lessons from the present study highlight considerations that are necessary in order for interdisciplinary reform efforts to become a reality. Interdisciplinary connections should be more easily implemented in elementary school than middle or high school; however, a number of obstacles remain. The emphasis on standards-based high-stakes testing has resulted in diluted curricula at all levels, including elementary schools (Amrein & Berliner, 2002). The pressure for teachers to focus on tested subjects and only tested topics within those subjects has watered down curriculum across the United States and impedes efforts to provide students with opportunities for science inquiry and exploration. For new research to filter into schools, teachers need support from administrators, researchers, and parents, among others. Support includes time for professional development for learning new material, planning, and collaborating with researchers and other teachers. An acknowledgment of standards alignment and technology support will also benefit education reform, justifying teachers' perceptions of interdisciplinary curriculum as meeting multiple discipline and standards-based goals rather than “fitting in” to their already full school schedules.

In the present study, BioMusic scientists offered support by providing content, materials, feedback, and their time. More scientists need to devote their time and effort for science education reform (Crosby, 1997). Effective interdisciplinary instruction can provide opportunities for students to build 21st century skills and developing science literacy across disciplines. Breaking down the subject area barriers can contribute toward reform, allowing teachers to help sharpen students' connections with the natural world.

The process of applying developing research ideas to elementary school classrooms requires collaboration between research scientists, project leadership teams, and innovative elementary school teachers. In this study, it was important to ensure that the interdisciplinary curriculum addressed the science and music education goals that are important in the context of public schools. The connection between the disciplines of music and science challenge the traditional separate subject area compartments found in many schools. Music and science face the additional challenge in elementary education of often being assigned subordinate roles with little time allocated. The implementation of innovative and interdisciplinary curriculum in elementary school is a collaborative process, which requires administrative support, infrastructure support, and a willingness to explore new ways of knowing (Driver, Asoko, Leach, Mortimer, & Scott, 1994).

Future Goals

New teams of teachers will be added to this project to develop more modules that incorporate BioMusic content and processes for elementary school students. Each lesson will be introduced to more teachers and students, refining and improving the lessons with each iteration and examining student learning. There is tremendous potential for expanding lessons covering a wide range of BioMusic research. In addition to studying the various animal species, other lessons will focus on the BioMusic scientists' research design and the applicable science processes.

Barab & Luehmann (2003) describe a central goal of curriculum development to design lessons that are flexible enough to allow teachers to adapt the curriculum to their circumstances and local needs. They also recognize that, “True reform is a collaborative process and involves working with teachers as partners” (p. 464).

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Appendices

Appendix A: Interview Questions

1. What do you feel is your greatest area of need in learning more about your specialty field (music or science)?
2. What do you feel is your greatest area of need in learning more about your teaching partner's specialty field (music or science)?
3. How comfortable are you with the curriculum writing process?
4. What is the greatest challenge you face in the writing process?
5. Do you feel confident that the curricular materials you develop for this project will be easily adapted to your school schedule?
6. Do you see any obstacles that would hinder incorporating these materials in the Fall? If so, what?

7. What value do you feel the music/science interdisciplinary connections will offer your students?
8. How much assistance will you need in learning about the complementary curriculum of this project?
9. Do you feel that you will develop appropriate comfort with the materials this summer to feel you can teach it to students this fall?
10. Do you feel that you will be able to share these materials and offer support to fellow teachers?

Authors' Notes

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