MUSIC, MATH AND SCIENCE:
TOWARDS AN INTEGRATED CURRICULUM

by

JEANNE BAMBERGER

(Editor's note: This paper documents the initial stages of research designed to investigate project-based activities that integrate music, mathematics, and science. It is expected that through these activities children will gain a deeper understanding of principles that are shared by, but uniquely embodied in each, of the three domains. The research project will continue in the fall of 2000 in K-3 classrooms at the Conservatory Lab Charter School (CLCS) in Boston and at Graham and Parks Alternative Public School in Cambridge, Massachusetts.)

BACKGROUND: MUSIC AND . . .

Previous research has suggested that musical studies have a beneficial effect on children's learning in domains of knowledge beyond that of music. (Rauscher *et al.*, 1993, 1997). However, the studies have been carried out over relatively short periods, and the causal factors that might account for this effect have not been made explicit. The studies described here examine these possibilities with differing means, over longer time periods, and in greater depth.

Drawing on previous work of the author (Bamberger, 1996), the projects juxtapose activities that embody underlying conceptual structures and problem-solving strategies shared by music, mathematics, and science. Projects are designed to focus on principles that are *functionally important* in each domain, while at the same time attentive to the differing characteristics inherent in each. Activities will involve varied materials (melodic motives/pattern blocks, drums/legos), invoke differing sensory modalities (sound/color, clapping/drawing), and will have potential for multiple representations.

Shared conceptual structures and strategies include:

Structures	*Strategies*
• hierarchies	• counting-measuring
• periodicity	• parts/wholes
• units	• similar/different
• ratio-proportion	• parsing/chunking
• symmetry	• classifying
• pattern	• naming
• constants-variables	

AN EXAMPLE

For example, consider that a child physically "keeping time" to a piece by clapping a beat is like a pendulum, marking off the continuous flow of time into discrete, invariant entities. In doing so, the child, like the pendulum, is embodying as knowledge in action the critical element we call a "unit." A unit, in turn, is the necessary basis for counting, measuring, and symbolically representing quantity.

But deciding *what kinds of features* to focus on as "things" to count — e.g., asking what *kind* of thing, at what level of detail, or according to what principle of grouping or differentiating?

JEANNE BAMBERGER IS PROFESSOR OF MUSIC AND URBAN EDUCATION AT MIT, AUTHOR OF *THE MIND BEHIND THE MUSICAL EAR*, A MEMBER OF NEW ENGLAND CONSERVATORY FACULTY, AND A SENIOR RESEARCH ASSOCIATE OF THE CONSERVATORY'S RESEARCH CENTER FOR LEARNING THROUGH MUSIC.

> **UNLIKE DESCRIPTIONS ON PAPER OR ALOUD, THESE DESCRIPTIONS INSTANTLY TURN INTO THE THINGS OR ACTIONS DESCRIBED. AND HERE SURPRISES ARE AT THE CRUX OF THE MATTER: THE QUESTION 'I WONDER WHY THAT HAPPENED?' BECOMES THE BASIS FOR INTERROGATION, REFLECTION, AND EXPERIMENTING, AND THUS EVENTUALLY FOR NEW IDEAS.**

— is a process that intrigues children during activities of reflectively performing and composing music. For instance, in listening and keeping time to a melody, some children will spontaneously clap and count different rates of beats (the basic beat or the measure); others might clap and count each of the actual notes that make up the rhythm of the song; while still others might choose whole rhythmic motifs as things to count. Even very young children are intrigued to puzzle over, discuss, and play with the different meanings they are giving to the seemingly simple actions of counting (Bamberger, 1998). Such questions merge into issues of boundary-making, classification, and naming, all of which are powerful constituents in the understanding and representation of phenomena across all three domains of knowledge.

SAMPLE COMPUTER ACTIVITIES

The curriculum series *Investigations in Number, Data, and Space* (Russell et al., 1998), which is currently in use in the experimental sites, emphasizes materials and an approach that interweaves both intuitive and functional aspects of musical structure. Moreover, *Investigations in Number, Data, and Space* is compatible with an interactive computer-synthesizer music environment, *Impromptu* (developed by the author) which will be available in the classrooms as a companion-piece to other music activities. (Bamberger, 1996 and 2000).

The computer plays a special role as mediator. Children move across modalities and media and between action and symbolic expression by making coherent objects in real time/space on the one hand (using legos, gears, pattern blocks, drums, keyboards, recorders), and on the other by making coherent objects in the virtual world of the computer (using graphics, drum pieces, melodies, geometric designs). But there is a difference: to make objects in the virtual world of the computer, children must begin by telling the computer what they want to happen. Moreover, unlike descriptions on paper or aloud, *these descriptions instantly turn into the things or actions described.* And here surprises are at the crux of the matter: The question "I wonder why that happened?" becomes the basis for interrogation, reflection, and experimenting, and thus eventually for new ideas.

An exercise using an early unit from the kindergarten level of the *Investigations* curriculum and a tune-building activity using *Impromptu* provides an excellent illustration. The *Investigations* unit begins with children building sequential patterns using pattern blocks. To make the sequential pattern explicit, to point up the processes of sorting and classifying, and to be able to compare patterns with one another, children are asked to label the constituents of their patterns—for instance, the repeating pattern, A-B, in Figure 1.

However, repetition is not always so obvious. For example, the repeating pattern A-B-B-A in Figure 2 may not be as clear as the pattern B-B-A-A. Why, we can ask, is that? What is a repeated element? What is it that creates "boundaries?"

PATTERNS IN MUSIC

Pursuing these questions, children learn to sing a song, for instance, "Hot Cross Buns," and then, working in the computer/synthesizer environment, reconstruct the song using *Impromptu*'s "tuneblocks." Tuneblocks are short motives that are structurally functional elements of a melody. Beginning by clicking on the icon labeled HOT (shown on the *Impromptu* screen in Figure 3), children immediately hear and listen to the whole tune. Then, clicking on each of the two patterned icons, they hear the two tuneblocks/motives that make up "Hot Cross Buns." "Dragging" the tuneblocks one-by-one into the Playroom, the children arrange and rearrange them, listening, watching the pitch-shape graphics unfold, until they have reconstructed the sequence of blocks that plays the whole tune, "Hot Cross Buns" (see Figure 3; for more, see Bamberger, 1991).

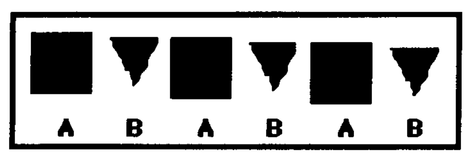


FIGURE 1

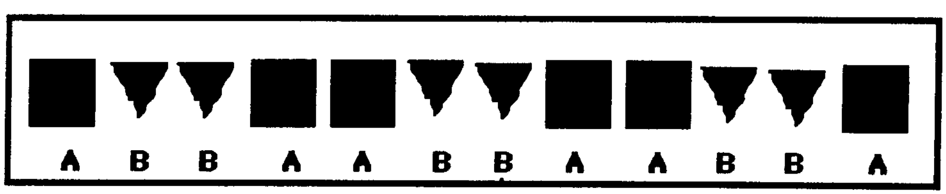


FIGURE 2

In this multi-media environment, *listening* to the completed pattern of tuneblocks and seeing the graphics, help the child also to *hear* the pattern of structure in the tune. As the whole tune takes shape in the Playroom and in the graphics window, patterns of melodic structure emerge—repetition, contrast, return. Moreover, as the children follow the pitch shape of the tune in the Graphics Window, they are also following the shape of each tuneblock at a more detailed level of representation. Thus, even the youngest children gain some experience with levels of detail and the potential for multiple representations (see figure 4).

MAKING MUSIC AND MATH

Returning to strategies borrowed from pattern blocks, children sort, classify, and label the tuneblocks for "Hot Cross Buns" (A A B A) much as they did the block sequences shown in Figures 1 and 2 (see figure 5).

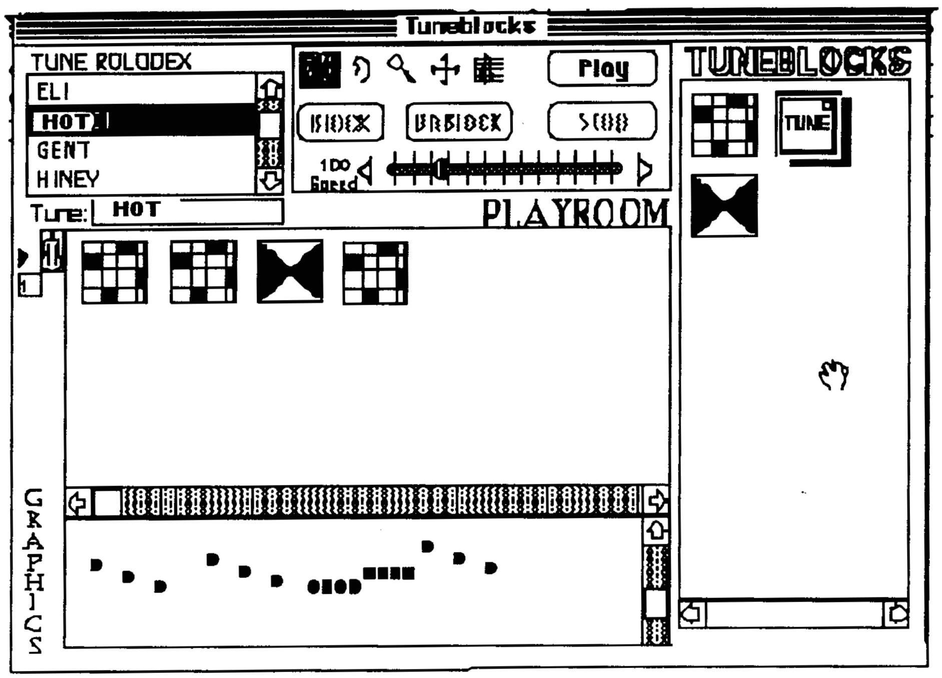
But important differences emerge. Pattern blocks are static, geometric shapes, squares and triangles that do not stand for anything except themselves. In contrast, tuneblocks icons are images, units of description, that simultaneously stand for and produce sounding/auditory units of perception. As a result, the same labels that might represent a sequence of pattern blocks (A-B A-B) may make a sequence of tuneblocks that produces a tune, but that tune, surprisingly, sounds funny. What, then, makes a tune sound "funny?" Is repetition of a tuneblock with the same name always the same even when it occurs in a different place — e.g. "A" at the end in contrast to "A" at the beginning of the tune? But is a pattern block with the same name different when it occurs in a different place? Is a sequence of pattern blocks ever "funny?"

All of which points to the importance of puzzling over differences. Even while differing media may share certain organizing principles, each medium has its own unique qualities.

CONNECTIONS TO MATH AND SCIENCE SKILLS

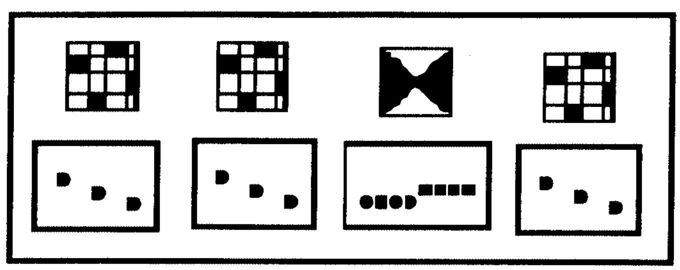
The questions then arises: Will the children make connections between real world activities such as singing and playing melodies, clapping rhythms, etc., and the principles these activities share with mathematics and science? To facilitate these connections, the following activities might be tried:

- The class is divided into two groups — one group is labeled the "A block" and the other group is labeled the "B block." They sing "Hot Cross Buns" (or other songs) by blocks, with each group singing their block in turn.
- Children learn to play "Hot Cross Buns" by ear on the Montessori bells (see Bamberger, 1994) or on the recorder or violin, still using the tuneblocks as "units of work"; then they create new



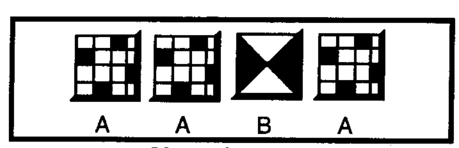
HOT CROSS BUNS RECONSTRUCTED IN THE IMPROMPTU PLAYROOM

FIGURE 3



Levels of Detail; Multiple Representations

FIGURE 4



Shared Labels

FIGURE 5

tunes by rearranging the same blocks.
- The class learns to clap just the rhythm of the tune according to the tuneblocks segments.

Questions that might then be considered include:

- How many blocks are there in the whole song? (Some may say four, some may say two).
- How many different *kinds of blocks* are there in the whole song?
- How many times is each block repeated?
- How come the same block can be a beginning and also an ending?
- How are the pitch contour graphics different from the tuneblocks representation? How are they alike?
- How is the sequence of computer icons different from the patterns made with the pattern blocks? How are they similar?
- How is playing Tuneblocks using the computer different from playing tunes on the bells?
- How is clapping different from singing a tune?
- How many claps are there in the whole song?
- How many claps in A?
- How many claps in B?
- Which takes longer, A or B, or are they the same? Is one faster than the other? How could you find out?
- Could you make bigger blocks that would also play the tune?

Returning once more to the mathematics unit, the children could now apply to their pattern blocks the kind of close attention that the above questions encourage. For instance:

- How many sides does a block (a hexagon, triangle, trapezoid) have?
- How many "points" does a block (hexagon, triangle, trapezoid) have?
- How many triangles fit into a hexagon (rhombus, trapezoid)?
- How are pattern block patterns different from and/or the same as the tuneblock patterns?

SCOPE OF WORK

We expect to begin work on this research project in the fall of 2000. The author and interns from MIT and NEC will work informally in K-3 classrooms at CLCS and the Graham and Parks Alternative Public School in Cambridge. Researchers will work with groups of 2-3 children in their regular classrooms twice each week. Sessions will build on activities in both music and the *Investigations* curriculum such as those described above, including rhythm, counting, aspects of "fast/slow," and perhaps even proportion. Sessions will be video-taped. During this period, the classroom teachers will be shown methods of actively integrating music activities into regular mathematics and science projects.

Twice each month, participants in the project (including classroom teachers and the researchers) will meet to review the videotapes and analyze results. We will watch particularly for instances of children noticing shared properties or principles across the various materials, media, and content areas. This might take the form of "seeing-as" (Smith et al, 1995; Wittgenstein, 1953), in which an activity such as working with pendulums might be "seen-as" similar to keeping time to a tune by clapping a beat, and both might be seen as the basis for constructing a unit to be used in counting and even for thinking about what we mean by "faster" or "slower." In this way, we would expect that the concepts and functions of periodicity and of a unit would be grasped as powerful principles to be used in other situations as well. We would also expect that some kinds of connections would be more readily accessible (e.g., patterns of repetition and periodicities), while some would prove more distant (e.g., symmetry, proportion, classifying). We would then re-examine the evidence to explore the nature of these differences.

OUTCOMES

At the end of this initial period we will have explored activities that are designed to help children develop their understanding of fundamental concepts shared by music, math, and science. As a result, we will have gained a sufficient sense of the activities' effectiveness to know whether these and similar activities warrant further development in other classrooms and with children of different ages. ¶

REFERENCES

Bamberger, J. (2000). *Developing musical intuitions: A project-based approach to making and understanding music*. New York: Oxford University Press.

Bamberger, J. (1998). Action knowledge and symbolic knowledge: The computer as mediator in *High technology and low income communities*. D. Schön, B. Sanyal, W. Mitchell (Eds.), Cambridge, MA: MIT Press.

Bamberger, J. (1996). Turning music theory on its ear: Do we hear what we see: do we see what we say? *International Journal of Computers and Mathematics Education, #1*.

Bamberger, J. (1991/95). *The mind behind the musical ear*, Cambridge, MA: Harvard University Press (Paperback Edition, 1995).

Rauscher, F.H. *et al*. (1993) Music and spatial task performance. *Nature*, p. 365, 447, 611.

Russell, S.J. *et al*. (1998). *Investigations in number, data, and space*. Dale Seymour Publications.

Smith, diSessa, *et al*. (1995) Misconceptions reconceived. *Journal of the Learning Sciences* 3 (2), pp. 115-163.

Wittgenstein, L. (1953). In G.E.M. Anscombe & R. Rhees (Eds.), *Philosophical Investigations*. New York: Macmillan.