Discovering the Musical Mind
A view of creativity as learning

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OXFORD UNIVERSITY PRESS
Chapter 6

Restructuring conceptual intuitions through invented notations: From path making to map making

Introduction

In this chapter I focus on a single, closely worked out example in which one child (whom I shall call Brad) invents a series of notations, each one a significant transformation of the one before. The Introduction is followed in Part I by theoretical background, where I place the study in relation to relevant theoretical material and also describe the fundamental distinction between path maker and map maker. Part II includes a description of the tune-building task and includes comparisons between typical path makers and map makers both in the music domain and in large-scale space. Part III is the Story of Brad, beginning with descriptions of the environment in which the study took place. I divide Part III into five phases tracing Brad’s evolution from path making toward map making. Part IV, Conclusions, summarizes and draws some implications for teaching and learning.

The transformations traced in Part III occurred during one brief session (about 45 minutes) as Brad worked with a set of tuned bells to construct, reconstruct, play, and notate the nursery tune, Hot Cross Buns. Each notation mediates a process of conceptual restructuring for Brad, while at the same time revealing to the observer his changing understanding of the entities and relations of the tune. Except for a few moments of interruption, all of Brad’s work was recorded on videotape.

Brad’s work in this one session closely resembles the kinds of restructurings that more commonly occur among children working on similar tasks over periods of several months, and then only with adult interventions (Bamberger, 1995). I argue that we follow Brad through a series of conceptual transformations that encapsulate and compress this process of moving from path maker to map maker. Moreover, in following Brad we are able to watch one of those rare instances in which spontaneous and significant learning is actually occurring in real time.

Part I—Theoretical background: A proposal

My proposal for how this process may evolve is borrowed, in part, from Bartlett in his seminal book, Remembering:

An organism which possesses so many avenues of sensory response as man’s, and which lives in intimate social relationship with numberless other organisms of the same kind, must find some way in which it can break up this chronological order and rove more or less at will in any order over the events which have built up its present momentary ‘schemata.’ It must find a way of being dominantly determined, not by the immediately preceding reaction, or experience, but by some reaction or experience more remote.

(Bartlett, 1932, p. 203, my emphasis)
Since we necessarily experience the world moving through time, our body actions as well as the flow of objects and events around us are necessarily experienced as successive and contiguous. My claim is that what we casually call creativity, with its ambience of myth and magic, often involves learning to step off these temporal action paths, to interrupt, selectively and purposefully, the natural passage of contiguous actions/events. Focusing on some chosen aspect, that aspect becomes the core of a new ordering.

Drawing on Bartlett, I will argue that to construct a “concept,” for instance, we must selectively interrupt the flow, the continuous succession of incoming sensory stimuli, to select, to pick out, and to recognize (by comparing backwards and forwards in time–space) a new succession made up of just those objects/events that are congruent with our current field of attention—all the “middle C’s” in a tune, all the numbers (selected out of the “natural” sequential order) that are multiples of four, all the objects on my desk that I can use for writing.

Heinz Werner puts it this way:

One who can shift his point of view in a purposeful grouping activity is no longer subject to the forces of sensory stimulation. He is able consciously to perceive that objects have different qualities, any one of which may be taken as the point of departure for an ordering process.

(Werner, 1948/1973, p. 240)

This is also a way of talking about classification: We may choose objects for attention because they share a common selected aspect; these objects then become members of a particular class of objects. So selective attention within the immediate (present) flow results in the construction of a new ordering even though the objects are disjunct, non-contiguous in time and space. This is one way we have of learning something really new—for coming to see in a new way.

Meaning making

I argue further that this process of interrupting the unique, contiguous sequences of everyday experience is a necessary step (perhaps the necessary step) towards learning to understand, to give meaning to, and to use the symbols that populate notation systems. This is because all descriptions, all sets of symbolic expressions, those invented by children as well as those associated with a community of professional users, are necessarily partial and they are so in two senses. They are partial in being incomplete, and they are partial in that they favor, or are partial to, certain aspects of the phenomena while ignoring others.

Philip Morrison has said of maps, the cartographers’ working notation:

Each map is in a way a theory that favors certain approximations. Procedures like selection, simplification, smoothing, displacements to make room, out-of-scale notation for bridges, streams, and roads so narrow that they would become invisible at true scale, enter inescapably.

(Morrison, 1991)

A. L. Becker puts the matter this way:

We are not so much compositors of sentences from bits as reshapers of prior texts. The modes of reshaping are in large part conventional, but also in some unpredictable part innovative and unpredictable . . . . A text has meaning because it is structuring and remembering and sounding and interacting and referring and not doing something else . . . all at once. The interaction of these acts is the basic drama of every sentence . . .

(Becker, 1984)
Both Becker and Morrison are concerned with how we make sense of texts. And if we consider that “text” may be a map, spoken discourse, or a musical notation (invented or otherwise), the tensions between these two richly drawn remarks help to illuminate some of the fundamental issues that will be our concern in what follows. Each of the two quoted authors construes the notion of text in a quite different way, suggesting, in fact, the distinction between path makers and map makers. The path maker’s path, like Becker’s compositors of sentences, is a response to ever-changing flux, a stream of events, a small drama, flowing through time. The path maker is making sense not so much through the crystalline logic of stable, consistent reference structures, but rather through a coherent interaction of “acts.” The map maker, favoring certain approximations, must convert real-time experience in following a path to conventionally biased but useful metaphor. As Morrison suggests, a map is the result of a series of generative, implicitly logical procedures that are made or plucked out from time.

To understand the “theories” implicit in these selective notation systems and to use their referents appropriately we must focus on the particular “favored approximations” underlying these conventional notations. For instance, in order to give meaning to the symbol for “middle C,” I have to extract instances of that pitch from their unique position—the context in which they are embedded and their unique function within that context. As we shall see, to carry out this process becomes a major step for Brad as he travels the course from path maker to map maker. As a result there will be moments when a particular event seems to be both the same and different from both itself and moments just past. The tensions, as we move between the two kinds of meaning making, capture in a subtle way the tensions involved when the boundaries of familiar distinctions become porous. And these in turn reflect the multiple ways in which we learn. Do we make sense of the sensory phenomena we encounter by playing out various rule-governed operations? Or does sense making involve, as Becker proposes, a set of prior texts that one accumulates throughout one’s lifetime, from simple social exchanges to long, semi-memorized recitations? 

. . . a set of prior texts that one accumulates throughout one’s lifetime, from simple social exchanges to long, semi-memorized recitations. One learns these “texts” in action, by repetitions and corrections, starting with the simplest utterances of a baby. One learns to reshape these texts to new context by imitation and by trial and error . . .

(Becker, 1984, pp. 136–7)

The contrasts between the two worlds of meaning making also raise questions about the role of “reflection” in learning. Although the term has accrued many meanings over time, distinguishing between only two can refresh and make more general the distinctions between path makers and map makers. The first, and the one we mean most of the time, refers to reflection on an object, subject, or idea—a stop-and-think. The Oxford Dictionary offers the following definition of reflection: “. . . the action of turning one’s thoughts (back) or fixing the thoughts on or upon a subject; meditation, deep or serious consideration.” Reflection, here, is an action, but it is an action that puts an object or subject “out there” at arm’s length to look at rather than to use. Reflection in this sense characterizes map makers. Stopping the continuous flow of time, map makers differentiate parts, name, test and make certain so as to say what they perceive—to hold still in description what otherwise might be unstable, uncertain, in flux.

Path makers are characterized by another, more interesting but also more elusive type of reflection—these are reflections of or in action. Rather than the time-out of stop-and-think reflections, these reflecting actions happen in real time, “telling” the path maker the next move to make. Reflection-in-action is balancing a tower of blocks, navigating the bumps on a ski trail, making a crescendo in playing a melody when we are hearing, anticipating, and doing all at the same time.
But these reflections in-the-moment easily go unnoticed; they are so fully embedded in a situation that we tend to see through them, noticing only their consequences. There is a kind of chaining, a series of linked moves. A move along an action path that triggers (a newly added block makes the tower of blocks wobble) is reflected in the responding move (a counter-balancing push). But the builder is now in the new situation (the tower is stable), the previous moves are gone, transparent to the current result, absorbed into the clear and present present.

John Dewey makes a similar distinction between the two kinds of reflecting. Dewey puts the distinction in terms of permanence and stability in contrast to evanescence and flux. He speaks, on the one hand, of "temporal qualities" that characterize immediate, present experience, and on the other, of "temporal order" which he associates with scientific inquiry.

Temporal quality is . . . not to be confused with temporal order. Quality is quality, direct, immediate and undefinable. Order is a matter of relation, of definition, dating, placing and describing. It is discovered in reflection, not directly had and denoted as is temporal quality. Temporal order is a matter of science; temporal quality is an immediate trait of every occurrence whether in or out of consciousness. Every event as such is passing into other things, in such a way that a later occurrence is an integral part of the character or nature of present existence. . . . Moreover, while quality is immediate and absolute, any particular quality is notoriously unstable and transitory. Immediate objects are the last work of evanescence . . . flux in which nothing abides.

While I find Dewey’s distinction between temporal qualities and temporal order useful and important, I take issue with his notion that “nothing abides.” I argue that while qualities experienced in moment-to-moment actions in a situation may be elusive, they abide and play a critical role in subsequent actions. Hasty puts it this way:

But because of . . . [an event’s] particularity . . . we shall not be able to retrieve such a past event for a postmortem. . . . True, the event has not vanished without a trace, but that trace is the mark the past can make on the present—on a new event or events, each with its own individuality and freedom.

(Hasty, 1997, p. 4)

The problem arises because we tend to believe in—to attribute “reality” to—that which we can hold still, take out of time or, in Dewey’s sense, put into temporal order by dating, placing, and describing. After all, these become the critical invariances we depend on not only for scientific inquiry but for matters of everyday life.

We tend, along with Dewey, to think of reflecting in-the-moment, including the actions involved in aesthetic experience, as something else—non-reflective, non-cognitive, undifferentiated. And in doing so, we are left with chalk ing up the successes of those whose work depends on these reflections situated in the moment’s actions to qualities inaccessible to explanation, to mystery and the magic of “creativity”—the expert cabinet maker, the child building complex Lego™ structures, the painter, violinist, or composer. But what, then, is guiding these actions in the situation—the craftsman’s smart hands, the painter’s painterly eyes, the violinist’s musical ear? We must at least posit a knowing mind making sense behind these sense organs (hands, eyes, ears) to which we give autonomous life. We say that “actions speak louder than words,” but because the active mind behind the moment’s actions doesn’t seem to speak at all, we feel uncomfortable attributing the results of these reflecting actions, this sense making, to “knowledge.” We admire and value the results, and even somehow cherish our failure to account for them.

Finally, and perhaps most important, I will argue that the goal of learning is not to overcome the behaviors associated with path making, but rather to have access to both action and symbol such that one is able to choose depending on when, where, and what for.

Part II—Path makers and map makers: The task and the materials

The task, as it has been presented to some 50 children between the ages of 8 and 12, and as it was presented to Brad, is as follows:

Build [a tune] with your bells, and then make some instructions so someone else can play the tune on your bells as you have them set up.

In preparation for the task, each child is given a mixed array of seven Montessori bells and a small mallet with which to play them (see Figure 6.2).
The Montessori bells are a rather extraordinary technological invention. Unlike any other musical materials that play different pitches, these bells all look alike. This is in contrast to, for instance, a xylophone bar that is relatively longer and is also lower in pitch or a piano key to the right of another, which is also relatively higher in pitch. Thus a child working with these bells must find differences in pitch only by playing them and listening.

Each individual mushroomed-shaped metal bell is attached to a wooden stem, with bell and stem in turn standing on a small wooden base, making it easy to move them about. Some stand on brown bases and others on white bases, but this single difference has no significance to the pitch properties of the metal bells themselves. Bells are played by striking them with the small mallet.

**Path makers**

Path makers build tunes by making a cumulating bell path. Searching through the mixed array of bells for a bell that matches the first event in the tune, path makers continue on searching, listening, and adding each found bell to their cumulating bell path, left → right, next–next–next. The result is a row of bells in which each bell is placed in the order in which it occurs in the tune.

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**Figure 6.2** Montessori bells and a small mallet. Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dockrell, and L. Tolchinsky (eds) *Notational knowledge: Developmental and historical perspectives*, pp. 81–112. © Sense Publishers, 2007, with permission.

**Figure 6.3** The “tune’s” bell path. Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dockrell, and L. Tolchinsky (eds) *Notational knowledge: Developmental and historical perspectives*, pp. 81–112. © Sense Publishers, 2007, with permission.
As a result of the sequential building procedure, the sequence of bells in a path maker’s bell path makes a unique, “one-purpose” instrument—it is made to play just this tune. Further, the spatial structure of the bell path—three bells, a gap, then two bells—is a physical embodiment of the motivic grouping or “figural” structure of the tune—a “figure” being the smallest meaningful structural element or “chunk” of a tune (see Figure 6.4). The beginning figure, which goes with the words, “Hot Cross Buns,” is embodied and played by the group of three bells. The middle figure, which goes with the words “One-a-penny, Two-a-penny,” is embodied and played by the second group of two bells. The ending figure returns back to the beginning figure again (6.1).

With regard to classifying pitches, as shown in Figure 6.5, the middle part includes two of the pitches (C and D) that are already in the first figure. However, the context in which each of the matched pitches occurs is quite different when constructing the tune in order of occurrence and also in playing the tune. Most importantly, the functions of these matched pitches are entirely different within their respective contexts. For example, the C in the first figure has a longer duration and is last in a descending progression. As a result of its position and function, this first C-pitch is an ending, the boundary marker of the first figure. The C in the middle figure has a shorter duration, is repeated, comes after a figural boundary and as a result functions as a beginning, a start-up after the “gap” of the previous boundary. For all of these reasons, typical path makers (children and musically untrained adults) consistently and understandably fail to recognize that these bells sound the same pitch. However, when asked specifically to listen for pitch matches, they are surprised to discover that “same pitch” was embedded in the tune. This is strong evidence to support the view that path makers do not listen across boundaries of figures and that their focus remains on the function of events within the figures of which they are members (Bamberger, 1995).

To play the whole tune, path makers make an action path through their bell path. As a consequence of adding bells left → right in the order of occurrence in the tune, the predominant direction of the action path is also left → right. However, there are three notable exceptions mediated by the structure of this tune itself (see Figure 6.6).
First, the repetition of the beginning figure, the first three bells, requires a “turn around” in the action path, a move “back” or right → left. Second, since the tune ends as it began, another turn-around is required to “go back” to play the beginning figure again. A third exception occurs in the middle part of the tune when single bells must be repeated even while the tune goes on.

These moments of interruption in the prevailing direction of motion form a sequential series of landmarks marking the boundaries of figures. The landmarks shape the structure of the action path, and it in turn coincides with the larger structure of the tune itself.

Invented notations for Hot Cross Buns are basically “iconic” trail maps, as shown in Figure 6.7.

The bells on the table are “copied” on to the paper as stick-pictures or sometimes simplified copies of the bells. But notice that the three bells on the table have become nine lines on the paper. The group of three bells is first drawn again to show “coming after”—that is, to show the immediate repetition of the first figure; the three marks are drawn again after the middle part to show that the three bells are played again at the end. This is, of course, a notational convention—that is, to show the immediate repetition of the first figure; the three marks are drawn again after the middle part to show that the three bells are played again at the end. This is, of course, a notational convention—one could show that while objects may remain stationary, events played on them are coming after one another? So “coming after” in paper space can substitute for “do it again” in action space. The notation for the middle section also shows the tension between static objects, the two bells on the table, and representations of events occurring on them. Here the static objects are given preference—each bell is drawn only once, even though each must be repeated several times. The difference here may be evidence, on the one hand, for the strong sense of the three bells forming a
group, and on the other for the difference between the player moving along on the bells, as in the three-bell figure, or the player staying put in one place as in the middle figure.\(^5\)

**Musical and spatial path makers**

As suggested earlier, there are interesting similarities between a musical path maker’s action path through the bells, and a path maker who is a walker in the city. For instance, Kevin Lynch in his book, *The Image of the City*, notices that a path maker follows:

> ... a sequential series of landmarks, in which one detail calls up anticipation of the next and key details trigger specific moves. ... In such sequences, there were trigger cues whenever turning decisions must be made and reassuring cues that confirmed the observer in decisions gone by. ... (Lynch, 1960, p. 83)

Thus changes of direction (turning cues) help to segment a journey and as such to mark the boundaries of spatial “figures.” Just as these landmarks are clues for the walker in the city, so changes of direction in actions on the bells form a series of landmarks on the path through the tune. And like musical path makers, walkers in the city simply go next–next–next within figures but do not construct relations across boundaries of figures or among landmarks.

The experience of musical path makers, like path makers in the real world, is of a journey that is paradoxically always in the immediate present while always going on. And the sense (both as feeling and as meaning) of this passing present is formed by the context of where the path maker just came from, while the passing present forms the context, in turn, for where he or she is going. Thus, for path makers, there is no comparing where they are to where they have been because there is no stopping, no stepping off the continuing path, and no means for comparing events that are distanced from one another in time/space.

**Map makers**

Musical map makers differ from path makers right from the beginning of their work on the task. As if needing to put themselves in order, these players first search in the mixed array for a subset of the given bells which they arrange from lowest to highest proceeding from left (low) to right (high). Leaving alone any “doubles” in the mixed array that match in pitch, the map maker’s arrangement forms an outside “fixed reference structure.”

![Figure 6.8](image_url)


Much like seriating a mixed array of sticks that are graduated in height, each bell added to the right is “higher” than the one to its left, and each bell added to the left is “lower” than the one to its right. Map makers are “uncomfortable” until they have first built this *fixed reference structure*—an all-purpose instrument in terms of which they “know where they are” and can plot this and many others.
other tunes. Thus map makers initially focus their attention on the *pitch properties* alone, rather than the path maker’s focus on order of occurrence and resulting situational function within the figures of a particular tune.

The property-ordered structure is an outside fixed reference in that it is *outside of any one tune, and yet its constituents are common to many*. And because its structure is based on the low–high ordering inherent in pitch properties themselves, the structure also implies a “unit of pitch distance.” This unit can be used to measure, along the reference structure, the distance between any two pitches—the “pitch interval.” The intervalic relations among pitches within a tune help to compare the structure of one tune with another.6

Perhaps these map-making tune builders are like travelers who are dependent on their printed map for finding their destination—looking at it instead of the objects and events that, for the path maker, shape the landmarks, the figures, and the feel of a particular moment along the way. Indeed, compared with a path maker’s bell path, the pre-ordering of the bells can hardly be called a “path” at all; rather, like a map, it is *an ordered terrain on which to trace a particular action path* (see Figure 6.9).

![Figure 6.9](image)

**Figure 6.9** Map maker’s action path on the fixed reference terrain. Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dokrit, and L. Tolchinsky (eds) *Notational knowledge: Developmental and historical perspectives*, pp. 81–112. © Sense Publishers, 2007, with permission.

As might be expected, the map maker’s notation path is no longer iconic but rather symbolic. There are no pictures of bells, only numbers (see Figure 6.10).

![Figure 6.10](image)

**Figure 6.10** Mapper’s notation. Reproduced from Bamberger, J. *The mind behind the musical ear*, figure 2.11. © Harvard University Press, 1995, with permission.
To construct their notation, map makers first number their bells from 1 to 5, going from low to high. Then, as they play the tune, they trace their action path along the pre-arranged bells “looking up” the number of the serial position in the reference structure for each tune event in turn. They, so to speak, peel off each found number, “transporting” it to the paper. Iterations of this process result in a row of numbers that designate, or point to, a sequence of bell positions, and these in turn target the player’s moves to the sequence of bells that plays the tune.

Notice that map makers need to use only three bells (C, D, E) instead of five to play the whole tune. In turn, mappers use only numbers 1–2–3 in their notation, and these refer to just the three bells that they have used in building the tune. This is in contrast to path makers, who use five bells, including the two doubles—that is, two Cs and two Ds. As pointed out earlier, the doubles are necessary for path makers because each one—each C and each D—has its distinct function within the boundaries of the figure in which it occurs. These differences are critical to the transformations in Brad’s work as he moves from path maker towards map maker.

The builders compared

The differences between musical path makers and musical map makers become more focused by comparing them with the differences that Piaget notices between younger and older children’s descriptions of journeys through the city. Piaget says of younger children:

... each journey shows a particular vantage point and [the children] are unable to bridge the gap between the privileged vantage point of one journey and the next... [E]ach is unique and therefore they cannot coordinate all the features in an area taken as a whole.

(Piaget, 1960, p. 16)

While with older children:

... each vantage point is no longer unique. The link between any two landmarks can be conceived of as dependent on the system as a whole. [Children] can now relate any one part to all of the remaining parts.

(Piaget, 1960, p. 18, my emphasis)

Coupling Piaget’s remarks with those of Lynch quoted above, we can say that musical path makers, like younger children, construct meanings in relation to the sequence and unique function of contextually situated reference objects or events (landmarks), where the occurrence of each object/event is a necessary condition for triggering the next move. Map makers depend for meanings on the mental construction of situation-independent reference structures in which objects/events are linked to one another and placed in a single coordinate space, and where distances among them can be invariantly measured independently of their occurrence or function in any particular situation or sequence of actions (Bamberger and Schön, 1991).

As a result of their consistent and singular construction strategies, path makers and map makers differ both in the bell paths they make and in their action paths on them. For path makers, given a particular tune, it is the bell path that is unique to the tune, the action path (basically from left → right, one bell at a time) remaining constant across tunes. For map makers, given a particular tune, it is the action path that is unique to that tune while the bell path (from left → right in scale-wise order, lowest to highest) remains constant across tunes. These strategies seem to be robustly consistent within the two groups.
However, unlike Piaget, who associates such kinds of differences with age and stage of development, I shall argue that experienced musicians make use of both paths and maps, and in fact move effectively between and within them in order fully to participate (as listeners and performers) in the complexity of a complex piece of music.

Part III—The story of Brad

The setting

While the beginning and ending points of Brad’s 45-minute session resemble the differences Piaget finds in children’s earlier and later descriptions of their walks, the findings must be differentiated from Piaget’s work not only in content, but also in experimental context.

- Time—Piaget gives us brief “snapshots” of different children at different times and at different ages and stages of development. Brad’s work involves just this single child and the conceptual changes that take place over a single period of about 45 minutes.

- Setting—The setting is not a neutral one. Brad’s work is carried out in the context of an alternative public school classroom called “The Laboratory for Making Things.” His notational inventions are influenced by the work of the five other 8- and 9-year-old children who were also working in the Lab on the same task.

- The Lab Culture—Brad is also influenced by the characteristics of a culture that has developed in the Lab over the seven years of its existence.

As an integral part of this culture, children were accustomed to informal conversations in which they explained to one another or to an adult how they were making sense of their working materials—blocks, foam core, drums, Lego™ bricks, and bells. They were also used to inventing some kind of graphic instructions/notations that could help someone else build what they had built. As in Brad’s work, this collaborative reflection led to learning from one another—rethinking understandings and descriptions, subsequently even influencing work on later projects that involved quite different materials.

As another part of this culture, children moved freely between building working structures with hands-on materials, and building working structures (graphic designs and also melodies) using the computer as a medium. As a result of this movement back and forth, certain kinds of ideas became part of the culture, influencing and illuminating the children’s understanding across all the media. For instance, there was the idea of “chunking” or grouping which initially emerged as they needed to “chunk” or parse a melody into workable “blocks”; these then became the “units of work” in composing melodies. The practice of “chunking” was also related to marking off elements that were to be named. This became most evident when we frequently heard one child asking of another as they looked together at a musical, Lego™, or other work in progress, “So what is a thing here?” Indeed, the question became a very concrete way of posing a fundamental ontological question: What have you got here? What are the objects, the “things” that your house or machine or melody is made up of and what do you call them? The question quite spontaneously focused a child’s attention on, for instance, functions, repeating objects, patterns, boundaries and groupings as they emerged.

I have grouped Brad’s work into five phases. Each phase marks a stage in the transformation of his tune-building strategies and his notation, and these in turn are evidence for changes in his way of understanding the tune itself—its constituents and their relationships to one another.
Phase 1: Brad as path maker

A. Labeling the bells

While Brad, at the beginning of his work, is in many ways a path maker, his first move has already distinguished him from more typical path makers. Apparently in anticipation of “making instructions,” Brad begins the task of building Hot Cross Buns by giving himself another task, namely labeling the bells. To do so, he cut out five paper squares, wrote numbers from 1 to 5 on them, and lining up the bells but without playing them at all, placed a numbered square in front of each bell. Ordering the numbers right → left from 1 to 5, he ingeniously invented a way to name the undifferentiated, anonymous objects on the table (see Figure 6.11).

While the sequence of Brad’s number names (1 2 3 4 5) may look similar to the sequence of map makers’ numbers, the meaning of the numbers is entirely different. Recall that map makers’ ordering and the numbers assigned to bells refer specifically to the perceived pitch properties of the bells—1 2 3 4 5 refers to the low (1) to high (5) ordering of pitches. Brad’s number labels cannot, of course, refer to the hidden pitch properties of the objects they name since, remaining silent, these properties have not yet been revealed. Only the arbitrary positions they happened to take as he put them out on the table determine the number names he gives to them. Of course, like “paste-on” labels, the number names are useful only as long as the labels stay attached to the bells. But Brad’s invention, like color-coded instructions for playing a tune on the piano, will make it possible to instruct another player which bell numbers to play when.

B. Building the tune

Playing the bells now, listening and searching for each bell as it was needed in the tune, Brad built up a cumulating bell path (see Figure 6.12). Being careful to keep the labels attached to the bells as he moved them into place, Brad transformed his initial silent line-up into a bell path where the position of each added bell matches its order of occurrence in the unfolding of the tune.
Listening and searching in his line-up, Brad finds the bell with which to begin the tune—it happens to be the last bell at the end of his arbitrary line-up, the bell labeled 5. Brad places the found bell in front of the others, carrying the label (5) along with it, at the beginning of the path that will play the whole tune. Playing his first bell (5) again, as if starting from the beginning of the tune, he searches through the remaining bells to find the bell for the next event. Placing it to the left of the first bell, he again is careful to move its arbitrary label (1) along with it (see Figure 6.12).

In this way, Brad transforms his initially silent line-up into a typical bell path where each bell is added in its chronological order in the tune. The result is a row of bells accompanied by what could appear to be a meaningless list of numbers, 2 4 3 1 5, going from right → left (see Figure 6.13). But the labels will serve Brad’s purpose well in making his “instructions.”

Brad’s sequence of bells on the table “holds” the sequence of tune events in the order in which they appear in the tune. In turn the labels below the bells arbitrarily name the sequence of bells—a quasi-notation path. His resulting bell path differs from that of the typical path maker in two ways. He consistently works from right → left, and his bell path has a corresponding “number path”—the labels that Brad arbitrarily attached to the bells.

**C. Making an action path**

Moving along on his built bell path, Brad made an *action path* through his unique, one-purpose instrument that played the whole tune. Brad’s *action path* was exactly the same as the typical path maker’s except for its prevailing right → left direction.

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**Figure 6.13** Bell path/number path. Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dokrell, and L. Tolchinsky (eds) *Notational knowledge: Developmental and historical perspectives*, pp. 81–112. © Sense Publishers, 2007, with permission.

As with other path makers, Brad's action path included three notable exceptions to the prevailing direction (here right → left), each of them mediated by the structure of the tune itself—first, the repetition of the initial figure which requires a move back or left → right, second, repetition on single bells in the middle figure, and third, another move back (left → right) to play the first figure again.

D. The first notation

Brad made his first instructions by so to speak “peeling off” each number name from a bell and placing it on his paper in the order in which he played them. In this way his sequence of actions through the bell terrain in table space becomes a sequence of numbers in paper space (see Figure 6.16).

Brad's notation strategy bears some similarity to map makers' notation strategy in that he also “transports” the number labels, rather than stick-figure pictures of the bells to the paper. But a closer comparison shows critical differences (see Figure 6.17).

The numbers in map makers' notation derive from and refer specifically to properties of the bells arranged in the fixed reference structure. Thus, seeing 3 2 1, the reader, following learned rules for playing on the all-purpose "instrument", will go "down stepwise" from high (3) to low (1) moving...
from right → left along the fixed bell series. While Brad's numbers also tell the player to follow a series of numbers, his arbitrary number names tell the player only where to go along on this single-purpose "instrument", and nothing about the pitch properties of the bells they are playing.

And there is another significant difference. Brad spatially groups his numbers (see Figure 6.17). The boundaries of Brad's spatial grouping also mark the boundaries of figures. These boundaries most noticeably coincide with changes in direction in his action path—that is, the switchbacks in the prevailing right → left direction, the immediate repetition of the opening figure (5 1 3) and its return at the end. The changes in direction “bundle” these events, helping to generate, along with the repetitions themselves, the figural or motivic grouping boundaries of the tune. The middle figure, which Brad notates as 4 4 2 2 2, is bounded by the move to new bells, the repeated events played on single bells, and by the subsequent return to the beginning figure. The spatial boundaries in Brad's notation thus mark landmarks that shape the boundaries of melodic figures.

In short, Brad's notation is a kind of structural analysis of the tune reflecting aspects that are not shown at all in map makers’ notations, or indeed in conventional staff notation.

Brad's spatial grouping boundaries bear a certain similarity to the historically early neumes in that they graphically represent contextually bounded figures (see Figure 6.18).


While the neumes were associated with the parsing of text, Brad's figures are more closely associated with the parsing of his actions. And like the early neumes, Brad's notation is primarily a performance aid, implicitly communicating to the performer how to express the internal structural relations of just this tune (Treitler, 1982).

In contrast to the outside fixed reference structure assumed by modern staff notation, Brad's bell path is what I shall call a reference entity. A reference entity is a uniquely built structure that "holds still" in physical space a maker's situational knowledge of some present phenomena—here particularly motivic/figural groupings. Like most reference entities, this one cannot be generalized so as to apply to another instrument, to comparison with another melody, or, indeed to structures in some other domain. According to Vygotsky, such context-specific groupings are typical of younger children:

. . . the composition of the group is determined largely . . . by a purely syncretic organization. . . . The syncretic image or group is formed as a result of the single elements' contiguity in space or in time, or of their being brought into some other more complex relationship by the child's immediate perception.

(Vygotsky, 1962, p. 63)
Finally, it is interesting that in putting pencil to paper, Brad simply abandons the prevailing right → left direction of his actions and spontaneously invokes the left → right directional convention associated with writing. Apparently the left → right convention associated with “notation space” does not carry over to “action space” (see Figure 6.19).


Phase 2: A discovery

In this phase Brad’s surprising discovery gives us insight into the kinds of unexpected situations that lead to creative conceptual transformations and to the emergence of new kinds of entities and their relations.

The transformations were triggered by an accidental discovery made by another child, Celia. Working on the same tune-building task, using bells with the same set of pitches, Celia set up her bells in a different configuration from Brad—with three bells on the left side for the first part, and two bells on the right side for the middle part.

After Celia had built and played the tune, she experimented a bit and discovered to her surprise that she could play the beginning of Hot Cross Buns “in two different ways so it sounds just the same” (seen from above in Figure 6.20).

Figure 6.20 “... it sounds just the same.” Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dokrell, and L. Tolchinsky (eds) Notational knowledge: Developmental and historical perspectives, pp. 81–112. © Sense Publishers, 2007, with permission.
A. Adapting Celia’s route

The discovery remained simply a mystery for Celia. But in the spirit of collaborative learning in the Lab, I showed Celia’s new way to Brad (see Figure 6.21) and asked, “How do you explain this? See if it will work on your bells.”

Brad played the first figure of the tune in his usual way and adapted Celia’s new action path to the shape of his bells for the repeat. Then pausing for just a moment, he went on to play the middle part of the tune in a new way as well (see Figure 6.22).

Figure 6.21 Celia’s way on Brad’s bells. Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dokrell, and L. Tolchinsky (eds) Notational knowledge: Developmental and historical perspectives, pp. 81–112. © Sense Publishers, 2007, with permission.

Using the two bells labeled 3 and 1, Brad played the middle part of the tune with the same bells that he had previously used only to play the first part of the tune. To complete the tune, he played the return to the first part in his usual way.

At this point, Brad stopped, looked up with an expression of puzzlement and surprise, and said “Oh, this is weird! I can play it with just three bells!” (see Figure 6.23). And he pushed aside the bell pair labeled 4–2.

Mediated initially by adapting Celia’s alternate route, Brad stepped off his familiar temporal action path, selectively and purposefully interrupted the natural passage of contiguous actions/events and, focusing on a chosen aspect, formed the core of a new succession. Brad’s discovery gives credence to my previous proposal (derived from Bartlett) that in some very fundamental way, coming to see in a new way is often triggered by stepping off a well-trodden temporal action path, in the process violating the boundaries of previously distinct entities while generating new ones. Adapting Celia’s alternative path, Brad interrupts his familiar felt path. Starting with bell 5, he violates the boundary of the first figure by jumping over bells 1 and 3, arriving at the end of the bell path. Traveling on bells 2 and 4, now in the opposite direction from his dominant right → left path, Brad re-creates his familiar opening figure in an entirely new way (see Figure 6.24).
Brad thus displaced bells 2 to 4 from their previous function as members of the middle figure, giving these bells new meaning as constituent members of the first figure. Continuing on left → right, he again crosses the boundary marking the distinction between beginning and middle figure. And once again bells change who they are. Bells 3–1, previously functioning as 1–3 when members of the beginning figure, now function as members of the middle figure. I argue that the events leading to this unexpected move are an embodiment of what Bartlett described as “a crucial step in organic development.” Brad found a way to “break up the chronological order [of his bell and action paths] and rove more or less at will in any order over the events” (Bartlett, 1932, p. 206).

Piaget comments on the important effect of taking “detours” on children’s evolving conceptions of large-scale space. Piaget says of children’s alternate paths in getting from home to school:

Operations . . . are found formed by a kind of thawing out of intuitive structures, by the sudden mobility which animates and co-ordinates the configurations that were hitherto more or less rigid despite their progressive articulation. Each detour leads to interactions which supplement the various points of view.

(Piaget, 1960, p. 38)

Piaget’s insights, including the conceptual leaps that detours portend, and the logic implicit in them, bear an eerie similarity to Brad’s “detours” in traveling in the very small space of his bell terrain.

B. Brad explains

While it might seem, to those who read and perform music from standard notation, that Brad simply recognized the bell pairs 4–2 and 3–1 as matched pitch pairs—both pairs of bells play pitches C and D. But jumping ahead a bit to Brad’s own explanation, he makes it clear that this is not the case. When asked by Mary Briggs, “How’d you discover it? All of a sudden you said, ‘Wait a minute, I can do it with three,’” Brad explained:

. . . I was realizing that if I could play it one way—like 5 1 3 (pause). Then I realized that two of these (points to the pair [1 3]) could be used in a different way instead of these two (points to the pair [4 2]).
An unpacked version of Brad’s compact account might go something like this:

Using all five bells, the two pairs of bells, 1–3 and 2–4, work equally well for playing the beginning figure—either 5–1–3 or 5–4–2. These same two bells, 2–4 and 3–1, can be swapped to play the middle figure, too. And since these two bell pairs can substitute for one another to make both the first and middle figures, they must be functionally equivalent pairs!

Brad articulates that principle in his expression “. . . could be used in a different way instead of . . . ” (see Figure 6.25).

![Figure 6.25](image)


And the final logical leap is that since the two pairs are functionally equivalent, either one pair or the other plus the single 5 bell is enough, and that makes just three bells in all.

Looking back at the sequence of events in this phase of Brad’s work, I will argue that his insights provide evidence that constructing a class of functionally equivalent objects/events is perhaps a necessary intermediary step towards, but is not the same as, recognizing matched pairs of decontextualized pitch properties—here the class of all Cs and all Ds.

But I want to emphasize that, as in most on-the-spot learning, Brad’s reasoning was emergent in real time and as such was almost entirely embedded in his actions. Indeed, judging from the way he expressed his discovery, “Oh, that’s weird; I can play it with just three bells,” his creative cognitive leap apparently felt to him, at the moment, more like magic than a series of logical steps such as I have proposed.

**Phase 3: Making the three-bell theory work**

Phase 3 marks the working out of transformations that were imminent in Phase 2. Pushing aside the two “extra” bells (2 and 4), Brad successfully plays the whole tune using just the three remaining bells labeled 5 1 3 (see Figure 6.26). His second notation gives instructions for how to go on just those three bells (Figure 6.27).
Brad’s three-bell notation might seem in some ways to resemble a map maker’s notation, but again there are important differences. The number labels that Brad uses [5 1 3] are still the arbitrary labels he attached to the bells at the outset; as such, they do not refer at all to pitch property or fixed reference numbers. And perhaps more important, Brad’s spatial grouping of his numbers
continues to reflect the figural/motivic structure of the tune—something not represented in the typical map maker’s notation (see Figures 6.28 and 6.29).

Looking with Brad at the finished notation, Mary’s probing question leaves no doubt about these groupings. Circling the middle row of numbers, Mary asks:

M: Now, Brad, how come you put all those together?

B: (rather haltingly) Because they’re kinda together . . . cause it’s kinda the same . . . it’s the same as these three. (Brad points to the previous three numbers, [5 1 3]).

Brad’s use of “the same” is noticeably different from conventional usage in relation to pitch. The events numbered [3 3 3 1 1] are “the same as” those numbered [5 1 3] in just one critical respect: “they’re kinda together” to form gestures or structural entities. To use the children’s expression, events that form a group constitute the functional “things” of this small universe—what we would call the structural entities of the tune.

Actually, Brad gave us previous evidence that he thinks of a figure as an entity. In response to Mary’s initial request to “write down how you’d do it that way,” he said, as he began to write, “The first two are the same”, and he copied out [5 1 3] [5 1 3].
As suggested earlier, it is clear that Brad is referring not, for instance, to just the first two discrete events (e.g., 5 and 1), but rather to two whole entities—the "objects" are figures. Werner confirms this “early ontogenetic” sense of “togetherness” as expressed in language:

The primitive type of classification based on togetherness of different things in a realistic situation can be clearly observed in the early ontogenetic stages of child language. . . . The inner relationship expressed in the child’s collective naming of things is fully intelligible only when referred to the fundamental principle that primitive classification is rooted in the concrete naturalistic situation.

(Werner, 1948/1973, p. 225)

Phase 4: Brad’s reflections produce a third notation

Brad’s third notation not only reveals how he is re-thinking the constituents and relations of the materials. The new notation also reveals the surprising potential that an invented notation has to uncover assumptions hiding in our conventional notations.

Brad’s next moves seem clear evidence for the significance Bartlett has given to “turning back” on one’s own “schemata” and constructing new ones:

[An organism] has somehow to acquire the capacity to turn round upon its own 'schemata' and to construct them afresh. This is a crucial step in organic development.

(Bartlett, 1932, p. 206, my emphasis)

A. Seeing a pattern

Mary helps Brad to “turn round” by referring to a conversation that had occurred just a moment before. Mary says, “Now, Brad, you told me you saw a pattern. What was the pattern you saw?” Pointing to each of the three bells on the table as he gestures, still going from right → left, Brad says in quick response to Mary’s question: “Well, you could really number them 1–2–3; 1–2–3.”

Figure 6.30 “. . . you could really number them 1–2–3; 1–2–3.” Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dokrell, and L. Tolchinsky (eds) Notational knowledge: Developmental and historical perspectives, pp. 81–112. © Sense Publishers, 2007, with permission.

And re-assigning his numbered paper squares, Brad relabels the bells accordingly.


In doing so, Brad has replaced his ad hoc number names (5–1–3) with conventional ordinal numbers that refer to and correspond with the sequence in which the bells enter the song as tune events. In giving up the arbitrary number names, Brad creates a whole new reference system.
These are numbers that refer unambiguously to an apprehended world—a row of objects on the table that, when played, create events as they occur in real time. Using this new reference entity, Brad’s verbal instructions for playing the tune, along with his gestures, become an embodied action notation. And with this, the bells suddenly take on directional meaning with respect to pitch. He says, gesturing to show the directionality, "Let’s say this was 1." And he continues:

Then you would go like 1–2–3.
“Then you would go like 1–2–3. Which is high, 2–2–2, which is a little lower, then 1–2–3.

So you go up, and then up again, then you go down, and then up again.

This episode and its evolution raise new puzzles and new issues. For instance, Brad speaks as if asking “you,” the receiver of his instructions, to walk along his numbers and bells, “going up” and “going down.” But numbers do not literally go up or down, and we are not literally “going up” or “going down” either as we follow Brad’s directions.

Notice that Brad’s description, “So you go up...,” corresponds exactly to our conventional usage when we say of the number line, the numbers “go up.” Animating numbers, putting them into motion, we are of course invoking a metaphor—a static list, a chronology stuck in space, comes...
alive as if acting in time and motion. But these metaphors are so deeply embedded in our language that we have forgotten that the terms “up/down” and “high/low” literally only refer to visible, tangible objects that can move or can be moved up and down through time in space.

Further, in adopting this new notation, Brad wipes out a central feature of his previous “instructions”—the notation as a physical embodiment of the tune’s figural structure. Recall that Brad’s initial bell path was constructed in synchrony with the chronology of events in the tune. In turn, his initial notation path was spatially grouped to reflect the tune’s motivic structure. Over the last set of moves, Brad has gradually broken this synchrony apart. And now, with his ordinal numbering of the bells and his focus on directionality, he almost entirely abandons any reflection of this figural grouping structure.

B. Metaphors, meanings, and notations

Brad’s newly invented number scheme and his use of metaphorical spatial/temporal language reveals a paradox, and the paradox in turn helps to reveal aspects of notational conventions that ordinarily can remain comfortably hidden in their common use and practice. Dead metaphors can come alive under conditions of uncertainty and confusion.

The paradox arises because similar spatial, directional, and motion metaphors are embedded in the terms we use to refer to pitch relations, as well as numeric relations. Just as we speak of numbers “going up” or “going down,” so we speak of pitch “going up” or “going down.”

Carrying this sense of apprehended movement into our language, we come to believe it—we attribute movement to melody itself, as if pitch and melody were self-animated. And in similar ways, we attribute self-animation to numbers when we encourage children to say as they move along a number line, “The numbers are going up.”

But the sense we have of a melody “moving” is a mental construction like the frames in a moving picture that give the impression of movement. However, taken literally, it is performers who move, not pitches. Once built, neither the bells, their pitches, nor the notation on paper literally move anywhere. It is Brad who moves.

In making his new instructions, Brad is focusing on the self-animation we attribute to numbers, not the direction of pitch motion as we sing or play the tune. And here the potential for confusion in metaphorical meanings becomes intense. Looking back at the map maker’s notation based on the “motion” of the pitches within the fixed reference structure, the beginning of Hot Cross Buns in fact goes down, not up. The first two figures are numbered 3 2 1 3 2 1. To make Brad’s notation which he consistently writes right → left match conventional notation, which is, of course, written left → right, the sequence of numbers under the bells, as well as the direction of motion in his notation, would have to be exactly reversed (see Figure 6.33).

![Figure 6.33 Crossed metaphors. Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dokrell, and L. Tolchinsky (eds) Notational knowledge: Developmental and historical perspectives, pp. 81–112. © Sense Publishers, 2007, with permission.](image-url)
So the paradox that seems inherent in Brad’s comment that the tune “goes up” when in fact it “goes down,” is really not a paradox at all. Rather we see a beautiful example of a difference in focus of attention. Brad has numbered the bells according to their order of occurrence in the tune—the numbers are ordinals—1–2–3 are the first, second, and third events. But once applying the numbers to the bells, the numbers change who they are—they become elements in a number line and Brad is moving “up” along that line. However, with a focus on conventionally represented pitch direction and assigning numbers according to music notation conventions, the sequence of pitches at the beginning of *Hot Cross Buns* is “going down” [3 2 1]. Both designations are right; it just depends on what aspects you are “partial to.”

**Phase 5: Pitch—An emergent phenomenon**

Thus far I have focused on Brad’s actions, his notations, and his words as evidence for his changing understanding of the tune structure. Through these actions I have proposed analogies with movement through space, specifically with making and following paths—“bell path,” “action paths,” “notation paths,” and alternate “routes” traversed. Moreover, I have attributed Brad’s insights to inferences he has drawn from observing and mentally coordinating his actions as he both made paths and followed them. Most of all, I have given causal importance to the moments in which these paths have been interrupted and their chronologies, their contiguous actions/events broken up.

I have also emphasized the importance Brad gives to figures—these are the “things,” the units of perception reflected in his written notations. But with his mostly verbal, gestural third notation, these figures as units of description have essentially disappeared.

While all of these transformations in action give evidence of emerging new entities and relations, none of Brad’s notations referred to pitch or pitch relations as such. Recall that with the bells all looking alike, pitch remains a hidden property of these unidentified objects. To build the tune Brad had to play the bells and listen for a match between the bells he heard and the tune in his head which he had sung and at times continued to sing as he went along. In building the tune and playing it, Brad necessarily did this pitch recognizing entirely “by ear,” in action, and in the local context of the tune in its becoming.

It is not surprising, then, that none of Brad’s three notations referred to pitch or pitch relations as such. The notations refer, in one way or another, to the ordering of bells as he has set them up in a row, to the sequence of tune events as coordinated with his actions, and, except for the last, to the grouping of these tune events into the figures of which they are members.

Watching Brad’s work, I asked myself what on-the-spot intervention might help him to account for his insights and for the inferences that led to them. It was my hunch that Brad would need to shift his focus of attention to pitch as an inherent and invariant property of a bell, independent of the functional role of that pitch within figures. Such an intervention might also help him to account for the “weirdness” of his three-bell theory. This, in turn, could move him towards conceptual map making, hopefully without losing the relevant functional attributes of his present representations. In Phase 5, through a series of interventions, I began the process of trying to carry out this program with Brad.

**A. Matching pitches—another surprise**

Pointing to the two “discarded” bells, I asked Brad: “How come you don’t need to use these bells? Do you know why it works?” Shaking his head, Brad said rather soberly, “No. I don’t.”
This response tentatively confirmed my hunch that Brad was unaware of the duplicate pitches in his initial five-bell collection. And the quality of his answer—pensive, reflecting some puzzlement—suggested that this was, indeed, something new for him to think about.

To help Brad isolate the pitch properties of the bells, taking them out from their structural functions when embedded in the tune, I made an intervention of a more directly instructive kind. Pointing to one of the “extra” bells standing apart from the three-bell tune path, I said, “Can you find another bell that sounds the same as this one?” This was a version of stepping off a well-trodden path of actions; instead of tune events, the bells could just play matching sounds (see Figure 6.35).

**Figure 6.34** “No, I don’t.” Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dokrell, and L. Tolchinsky (eds) *Notational knowledge: Developmental and historical perspectives*, pp. 81–112. © Sense Publishers, 2007, with permission.

**Figure 6.35** … find one that sounds the same? Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dokrell, and L. Tolchinsky (eds) *Notational knowledge: Developmental and historical perspectives*, pp. 81–112. © Sense Publishers, 2007, with permission.
Playing the "extra" bell and testing each of the others, Brad immediately found a match for the designated bell. This was important proof that he had no problem actually recognizing matched pitches. However, he was visibly surprised to discover that matches were to be had—good evidence that this was a whole new view of the situation.

Quite spontaneously, Brad moved the matching “extra” bell over to position it together with its mate (see Figure 6.36).


Having found one pair of bells that matched, Brad pushed the remaining “extra” bell over towards the bell labeled “3.” And without even playing it, he said aloud, “And these probably do, too.”

Figure 6.37 “And these probably do, too.” Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dokrell, and L. Tolchinsky (eds) Notational knowledge: Developmental and historical perspectives, pp. 81–112. © Sense Publishers, 2007, with permission.
Testing the remaining bell with its hypothesized match, Brad positioned the new matches together to form pairs (see Figure 6.38).

Figure 6.38 Bells that sound the same. Reproduced from Bamberger, Restructuring conceptual intuitions through invented notations: From path-making to map-making, in E. Teubal, J. Dokrell, and L. Tolchinsky (eds) Notational knowledge: Developmental and historical perspectives, pp. 81–112. © Sense Publishers, 2007, with permission.

With the matches completed he had also completed a new kind of embodied notation. The bells were no longer objects that played tune events, but rather objects that “sound the same” as one another. The bells had once more changed who they are—once functionally equivalent, they were now simply pitch-matched pairs. And leaving no doubt as to his new understanding, Brad pushed the two extra bells away again, and said: “So you really only need . . . that’s cool!”

Brad had made an important move from situation-dependent, functional meanings toward classification according to de-contextualized properties—a critical step (perhaps the critical step) in the evolving conceptual change from path making toward map making. And having plucked out from their functional context just those bells/pitches that share the same hidden pitch property, he had found reason to be convinced that his three-bell discovery was not so “weird” after all; you only do need three bells—“ . . . that’s cool.”

Part IV—Conclusions

Path, maps, and educational implications

I began the story of Brad with a proposal concerning learning. Learning, I argued, is often learning selectively and purposefully to interrupt a necessarily temporal passage of contiguous actions/events by focusing on a chosen aspect. That aspect now becomes the core of a new succession made of just those objects/events that are congruent with a current field of attention. Looking back, what evidence do we find in Brad’s work to instantiate this proposal? And what does Brad’s work tell us more specifically about the processes of transformation in moving between path making and map making? The initiating moment in Brad’s evolution occurred when, mediated by Celia’s alternative path, he was able to break up the chronological order of the tune events and “rove more or less at will in any order over the events.” Learning from the effect of this “break-up” of his “felt path,” Brad mentally coordinated, in one representational space, objects/events that had belonged to separate spaces. He could substitute bells for one another, different bells could be used to serve the same purpose—they were “functionally equivalent.” Constructing a class of functionally equivalent objects was a necessary intermediary step towards recognizing matched, de-contextualized pitch properties. Through my intervention in the matching task, Brad came to see pitch property as a differentiated “thing,” an object of attention in itself.

Brad, with help, had made forays toward becoming a musical map maker, but he was not yet there. He had yet to construct a whole new sequence based only on pitch properties—that is, a functioning fixed reference grid in relation to which he could position any pitch, and measure its
distance from others—an all-purpose instrument upon which he could play any tune, compare one with another, and unambiguously notate them.

Assuming, as I have suggested, that Brad’s work gives a glimpse into the conceptual changes involved in moving from path making toward map making, we are left with a fundamental unanswered question. How can we help children acquire the security and the communicability of fixed-reference, property invariance structures while continuing to develop the musically critical sense of figures and pitch functions in the unique context of an unfolding melody or even larger musical composition?

Ideas of style, genre, and form; laws of harmony and counterpoint; analyses of the ideological determinations of music’s production and reception—these and countless other imaginative constructions have enabled theorists to speculate on the determinacies of musical experience. But in our zeal to explain music, it has been tempting to forget the hypothetical and constructed nature of such categories and to imagine that it is these ideas themselves that have the power to produce our experience . . .

(Hasty, 1997, p. 8)

Finally, what are the more general educational implications of the distinctions between map making and path making? Consider that it is traditionally the case in schools, for instance, that symbolic conventions serve as the “spectacles” through which we see and judge a student’s work. We look for either a match or a mismatch with convention, and a match with conventional practice is judged correct.

But on this basis for evaluating student work, Brad’s notational inventions would run a serious risk of being seen as simply wrong. Most important, such evaluation would miss seeing Brad’s notations as a vehicle for revealing to himself and his teachers, the cognitive work involved in his reasoning, his logical inferences, and the creative transformations they entail—in short, creativity as learning.

What we are witnessing in Brad’s multiple descriptions/notations is a stunning example of the multiplicity of criss-crossed intersections between notational conventions and inventions. Through these intersections and confrontations, we witness the possibility that invention can illuminate convention. However, questioning our notational conventions is a risky business because notational conventions shape our perceptions like eyeglasses that we look through. Reversing this habit, looking at our notational conventions through the glass of a child’s inventions, we can begin to see aspects inherent in our conventional symbol systems that otherwise remain hidden from view. Perhaps this requires stepping off our well-trodden, well-learned symbolic paths to participate in and value the “felt paths” that we know best from moving about and being alive and well in the world of sensory experience. “Out of that tense multiplicity of vision [comes] the possibility of insight” (Bateson, 1994).

Acknowledgement


Notes

1 The term “reflection-in-action” is discussed in other contexts in Schön (1983).
2 It should be noted that most children are not very familiar with the words for Hot Cross Buns.
3 An “x” marks a tap on a bell, while the lines and arrows mark the direction of the path maker’s actions through the bells.

4 This demonstrates what diSessa and colleagues describe as metarepresentational competence (diSessa et al., 1991).

5 Children often play the middle part of the tune with only three repetitions on each bell even though the song, properly sung, includes four repetitions. This also provides some evidence that the children do not usually know the words of the song—that is, one-a-pen-ny needing four notes, not just three.

6 Since this collection of pitches includes only a subset of the possible (12) pitches used in Western music, and they are related by a non-constant interval, strictly speaking this ordered collection does not provide an invariant unit with which to measure “pitch distance.”

7 See Chapters 7 and 12 in this volume for more information on The Laboratory for Making Things.

8 Mary Briggs was the Special Education teacher who worked with Brad and the other children whom she brought to the Lab each week. Mary was not only very familiar with the children, but remarkably sensitive and responsive to their special insights and creative abilities. Rodney was working on the bell task next to Brad.

9 It is significant that Werner calls this kind of grouping “primitive,” reflecting again the bias in developmental theory towards invariant reference structures. However, grouping in response to situational events is as critical to perception and performance as the invariant properties which are taken as the goal in developmental theory and often in musical instruction as well.

10 This convention seems to imply some kind of quantitative meaning and, with this meaning, the numbers would be considered cardinals instead of ordinals. That is, instead of next–next–next as with ordinal numbers, the expressions “going up” and “higher” could be understood as literally implying more–more–more. Wittgenstein describes a similar situation in the Brown Book in his discussion of “language games” (Wittgenstein, 1965, pp. 79–84). Indeed, we could see Brad as participating in language games of his own invention.

11 K. S. Lashley, in his classic paper of 1951, “The problem of serial order in behavior,” speaks of the relation between syntax and action: “. . . the syntax of the act which can be described as the habitual order or mode of relating the expressive [symbolic] elements . . . to the generalized schema of action . . . determine the sequence of specific acts, acts which in themselves or in their associations seem to have no temporal valence” (Lashley, 1951, “The problem of serial order in behavior”, cited in Pribram, 1969, p. 525).

12 “We describe the behavior of s by saying that the sum s approaches the limit of 1 as n tends to infinity . . . ”

13 Evidence that Brad was quite capable of distinguishing “up and down” in pitch was clear when, on the next day, hearing the beginning of the same tune played by the computer synthesizer, he said quite spontaneously “it goes down.”

14 I use Brad’s original labels for the bells here, so as to make it easier to describe the inferences he now makes.