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Mathematics and the Feldenkrais Method: Discovering the Relationship

Typically in mathematics classrooms ranging from elementary to college level, math teachers, supported by their textbooks, present a model way of thinking about their subject which, when followed, will enable a student to solve any kind of problem. Often, the class divides itself into two loose camps: those who already think according to the model, and those who think in another way. Those whose thinking style matches the model will tend to succeed early on and will be rewarded. The rest of the students are left with a choice: Think like a mathematician or accept failure. Most of the time the teachers, who were themselves the types that naturally matched the model, will be unable to offer their students any explanation of how to change one's thinking style and will instead stick to the surface elements of math instruction: drilling, memorization of formulas, getting the right answer.

Both the "math types" and the "non-math types" will lose as a result of this approach. Obviously those who cannot adapt their thinking by themselves, even though they may be extremely bright and capable, will be forced to resign themselves to failure. But the "math types" will also suffer because, failing to understand their own thought process, they will often not be able to improve it when they reach a more formidable math challenge. The success/failure striation will continue to weed students out and only a very few will ever make it to the truly exciting regions of mathematics. Through all of the weeding-out process, the aspects of math that are most interesting and beautiful will be lost to everyone engaged in the shuffle of "who is better than whom."

I had always desired a way of bridging the gap between "math types" and "non-math types," and the Feldenkrais Method of somatic education, with its focus on limitless improvement and making the impossible possible, seemed to offer a flicker of hope. Nevertheless, it took a good deal of time and self-experimentation before I was able to use the Method to begin to understand the process of mathematical thinking in myself.

I imagined being able to retain my calculus the way I had retained arithmetic. I craved an ease of motion in my mind, an alternative to the stiffness, the spasmodic clutchings at the back of my head, and the sense of panic I got looking at the symbols and numbers. I wished that there was a potion I could drink that would enable me to think clearly, blowing the fog off of my thoughts so that I would be able to see without impediment in any direction.

I believed that magic potion was "the perfect math teacher." He or she could explain things to me in such a way that the subject would become very easy, so that in a single glance, I would see all of mathematics' inner workings and understand how they fit together. I imagined such a teacher must exist, but I had never found him or her. Several of my math instructors were excellent; one of them used to give lectures that made me gasp, but I was never able to transfer those glorious explanations into my own head for keeps. This constant failing in the face of a genuine love for the subject of math was a source of real sadness and pain for me.

While working as a professional pianist, I went to a Feldenkrais instructor to improve my injured hands. The more I learned about Moshe Feldenkrais and his approach to educating the whole person, the more excited I became. When the opportunity came for me to take the four-year Feldenkrais practitioner training, I was thinking beyond the improvement to my body and began to imagine improving all of myself. I wondered if Moshe's work would confirm what I had always believed to be true: Mathematical ability could be improved in nonstandard ways. There might be a path of approach other than the traditional methods that had always failed me.

I was encouraged when my trainer, Carl Ginsburg, upon fielding some of my questions about mathematics, related a story that one time in Amherst, Moshe had written upon the blackboard the equation $\int f(x)dx=F(x)$. Feldenkrais had announced proudly to the class that this was what his Method was all about, that Functional Integration (FI) in math and in his work was one and the same. Both those with and without a mathematical background had been equally mystified, but no explanation ever followed.

I myself still lacked a fundamental understanding of basic calculus. I knew roughly what the symbols meant: They are the first half of the Fundamental Theorem of Calculus. Those symbols were put together in the 16th century by Sir Isaac Newton and Gottfried Leibniz, and they made possible an entire new world in scientific discovery. Still, my understanding of what those symbols actually represented was far gone from my mind. I had used them in high-school and in college, but I had never mastered their meaning.

I had desired to see if I could use the Feldenkrais Method to come to a better understanding of mathematics. Now I found that I would need a better understanding of mathematics to comprehend Feldenkrais! Somehow, the disciplines were related in a fundamental way. I thought it would be worthwhile to attempt my experiment, even though no one seemed to be able to offer me any kind of guidance for how to proceed.

VISION AND UNDERSTANDING

Galvanized by Carl's tempting story, I set out to determine if I could use Feldenkrais to improve my math skills in the way I was using it to change my body. Every day at lunch I walked or drove to the library on the college campus near our training facility and found a book on calculus of one kind or another. I would set myself in a comfortable chair and begin to read.

I put some constraints on myself. I wanted to be able to read a math textbook the way math professors do, straight through, without skipping around. Because I wanted to focus on the difficulty, I refused to do exercises with a pencil and paper. I would read, think, and nothing else, measuring my level of ability and understanding as I went. True to the Method, I would proceed only until I began to feel tired, at which point I would stop.

What I was really doing was learning to pay attention to myself while reading. The subject of the books had very little to do with the process, except for the nature of writing that math instruction requires. A math textbook is a particularly difficult thing to read. Each section is written concisely, with nothing extraneous added for detail or color, and the ideas in a given chapter must be comprehended thoroughly for the next chapter to make sense.

My reading skills in general were not good. Though I had always read voraciously, my ability to read quickly and for long periods had fallen off since fourth grade, about the time I started wearing glasses for near-sightedness. While my interest in books had not lagged, I had always been aware of how hard it was for me to sustain my attention. Mathematics and science textbooks demanded uninterrupted thinking and were very difficult for me.

So in those first library sessions I explored my ability to focus my thoughts while reading a sustained argument with lots of details, using the techniques of the Feldenkrais Method to improve those skills. By observing myself as I read difficult math concepts, I was becoming aware of how long it took to lose that focus on the page, and more importantly, of what kinds of things tended to cause me to lose it. Any improvement in mathematical skill would really come about as a fringe benefit of these experiments.

One of the mathematical exercises I set for myself was the complete comprehension of a well-known proof in mathematics: the proof that $\sqrt{2}$ is an irrational number. Like all sophisticated proofs, this one required keeping several complex ideas in my head while absorbing new information. I had always found the reading of such proofs very tiring, but now, in true Feldenkrais style, I had added the obstacle of not allowing myself to continue once I noticed myself straining. It is, of course, impossible for a beginner to read the complete proof in thirty seconds, and so I was enormously frustrated at my inability to make any progress! I was able to console myself with the notion that paying attention to myself in the act of reading was more important than feeling like a brilliant mathematician, but I did long for the reward of understanding the proof in the whole of its beauty.

I chipped away at the proof for a couple of weeks, stopping whenever I found myself looking at the words without reading them. One day as I read, I saw a detail that I had never noticed before. Understanding this overlooked detail brought the rest of the proof into clearer focus. As I found myself able to read a larger chunk of the argument seamlessly, I felt a powerful sensation of release in my eyes, as if they were no longer straining. It was very pleasant, and it served as a physical manifestation of my mental illumination.

But how strange! Why should the muscles around my eyes relax with the sudden understanding of a mathematical idea? The first answer that springs to mind is that I was straining to understand the proof, and when I finally did, I relaxed. If that were true, did that suggest the converse, that by relaxing my eyes I could have understood the proof sooner, that the "tension" in my eyes was retarding my math skills?

The converse of a statement is not always true: A duck is a bird, but a bird is not a duck. Nevertheless, as I continued to train in the Method, and as I continued to read about math on the side, I kept the experience of my eyes in the back of my mind, still not knowing exactly what to do with it.

As my vision changed dramatically over the four years of my training, I began to see more profound connections between vision and mental capacity. In lessons which involved scanning from left to right I noticed definite areas where my eyes jumped, refused to scan smoothly, and places where they could not really "see" at all. Having discovered these gaps, I began to work my way back into my body to explore the causes. Among other things, I discovered that limited flexibility in my ribs and hips had kept me from finding a comfortable way to sit and, unable to find a stable base, I could not easily adapt my head and shoulders to the demands of my eyes. As my training went on and I began to coordinate my ribs, head, and shoulders, I began to recover certain eye movements, including a smoother scan from left to right. The result on my reading, and subsequently my thinking, was profound.

There is a story by Kurt Vonnegut called "Harrison Bergeron" in which the government forces intelligent people always to wear earphones that produce loud sounds that intermittently startle them, so that they are never able to complete an intelligent thought. My difficulties in scanning brought a similar curse to me. Without realizing it, I had been unable to maintain my comprehension in an overly long sentence because I would lose the train of the words with my eyes. Over time I had learned to think very well in shorter gasps while neglecting longer arguments. I had excelled in producing spotty improvisations on the piano, short poems, and gesture drawings. I had avoided subjects like philosophy and logic. Books by 19th century authors like Dickens and Henry James, with their long compound sentences, had been nearly impossible for me to follow. Similarly, math textbooks, which, as I said, require a reader to follow a single train of thought for a significant duration, had provided a constant challenge.

As my visual acuity improved, my reading skills recovered and I found, to my delight, that I could comprehend long ideas from start to finish. A change had occurred in my vision, but it was reflected in my *mind.* I could read a mathematical proof all the way through without a break. I was better able to take in a long piece of music, another skill which had always caused me difficulty. Even my own writing reflected my new focus as I began to construct longer streams of ideas in my creative work.

The breakthroughs I experienced with my eyes were only one piece of a process I used to improve my whole self. There were other ways in which I was able to discover how the use of my body manifested the patterns of and hindrances to my thinking.

AN INNER SENSE OF SPACE

There are several levels of complexity on the road from counting to calculus. As children we begin with the number line. First we may master the skill of counting up from 1 to 10. Then we count backwards from 10 to 1. In time we will come to see the number line as a continuous road for which we have a single choice, left or right.

In arithmetic we learn to dance upon that line. By adding 2 and 3, we can leap over 4 to land on 5. Multiplying and dividing give us even greater leaps. Yet our calculations, while giving us infinite options to jump, still offer us only one choice, a single dimension of mental movement: left or right.

This level of functioning matches a child's needs. As infants we really only conceive of yes or no dilemmas: I am hungry / I am full, I am wet / I am dry. As we get a little older, we may become more sophisticated in our thinking, but we remain committed to the yes or no idea. I want this / I don't want that. I *really* want this / I *hate* that. Arithmetic is an appropriate skill to teach a child, because there is only one solution for every problem.

In algebra a new concept is introduced: the *variable.* This is the familiar letter x which can stand for *any number at all.* At first, the x merely replaces the blank in a common arithmetic equation, so "$2 + 3 = \_\_\_$" becomes "$2 + 3 = x$". Because we do not know what x is at first, we understand that it could be *any number,* and we need to find out which one it is. In this case the x can only be 5.

Algebra truly comes into its own when two variables are used together and allowed to play. Most often, x and y are the letters of choice. If I say "$x + 2 = y$" I am setting up a relationship between the variables: x and y can be any two numbers in the entire universe as long as x is two less than y. If x is 4, then y is 6; if x is 7000, then y is 7002; and so on. The equation $x + 2 = y$ has lots of solutions and you can plot them on a two-dimensional map, connecting them with a line. The more complex the relationship, the more that line wiggles around on the page.

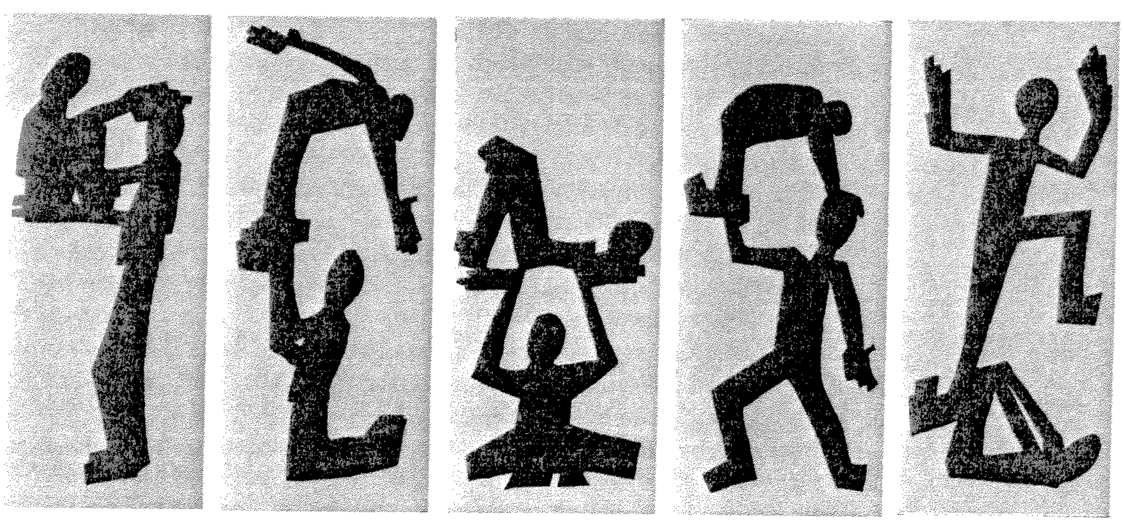
In order to understand algebra, a student must be able to recognize that an equation is not a problem asking for a solution, but an expression of a relationship, like a balanced scale. If you add something to one side and you want to keep it balanced, you have to add the same amount to the other side. Seeing the relationship between the two sides is more important than using it to solve a problem.

Even if we never learn algebra, understanding such interrelationships is essential for us to learn to move. At some point we realize that the parts of our bodies are connected through our center. When we roll, we do not simply take our shoulders in one direction. In fact, one shoulder moves up and the other moves down. In all human movement, there is a corresponding balance between parts of the system.

I had an adequate understanding of such algebraic relationships in high school, but when I reached calculus, I hit a wall. Even when I revisited the subject in college, I was unable to master its most basic ideas. Something about calculus was different from algebra. It was harder, not just in the way that adding was harder than counting, but in the way that comprehending algebraic relationships was harder than adding. It required a new dimension of thinking.

Just as with reading, I discovered a way to improve my grasp of calculus during my Feldenkrais training, this time by examining my sense of space. In the second year of my training, I had begun to notice that my self-image was physically inaccurate, but fit my ability to move. In my self-image I resembled a stick of gum, with width and height but no depth. Side-bending came relatively easy to me, as did forward and backward bending. I was comfortable with linear motion, but I had little to no comprehension of how to twist both forward and to the right, or other such moves. I rarely explored the functions that relied on these more complex movements because they were awkward and occasionally painful.

One day I also discovered that, instead of seeing depth, I was only comprehending two dimensions in space with my eyes. Every morning when I



looked across the gorge just outside our training facility I would compress the space of that half-mile of trees stretching down the hillside into a flat picture. I knew objects were closer or farther away only by their relative size. Physiologically there was nothing wrong with my depth perception, but I did not process the information very well in my mind.

Through various Feldenkrais lessons, as I began to gain an interior sense of the space inside my body, the world beyond my eyes began to look different as well. Objects took on a depth and solidity they had never possessed before. I could adequately gauge distances of far-away objects and could switch between near vision and far-away vision with ease.

The true turning point in my sense of internal and external space came in a series of lessons taught by Donna Blank in which she introduced Laban movement-concepts in an Awareness Through Movement (ATM) format. For a week I was asked to envision myself in the middle of a sphere and to make movements that took me simultaneously to varying places on its surface. I found the lessons excruciatingly difficult; they even made me angry. But I persevered because I was beginning to sense that I lacked something essential that would have made these lessons easier.

In fact, I was missing the *significance* of depth perception in human function. Recognizing the struggle I faced in Donna's lessons, I recalled many movements that had always been difficult for me that relied on a greater sense of three-dimensionality, an ability to see myself as fitting into a sphere as opposed to a circle: somersaults, headstands, even sitting comfortably on the floor, to list a few. These became easier when I started to fill out my internal image.

As I was coming to grips with what I lacked in my perception, I was also dutifully studying calculus. I had gotten in the habit of paying closer attention to what I was reading, having improved my ability to piece details together more effectively. While puzzling over theorems about limits, I contemplated sentences in my math textbook such as this one:

"There exists a number δ such that $0<|x-a|<\delta$ implies $|f(x)-L_1|<\varepsilon$"

It seems like a complicated sentence, and it is. But why? Just as in our previous equation, all of the letters represent numbers. In one sense, is it any different than $x + 2 = y$? Yes, it is different in an essential way, and realizing how it was different and what made it difficult provided me with the clue to connect my mathematical troubles with my inner sense of space and my ability to move.

To understand the meaning of each symbol in the above sentence, one has to differentiate between several classes of unknowns. There are layers of relationships at work between these variables, instead of a single interaction. When you decide what number x is, you automatically get a corresponding number for $f(x)$; the two are related like x and y in $x + 2 = y$. But while x can be *any number* in the world, a must be a particular number; it stays still as x moves, the way a shoulder might remain still while the arm explores a range of motion. Finally, δ represents the relationship between the two; it stands for the *shrinking space* between the moving number x and the fixed number a.

There is a larger relationship at work between that first group of variables and the rest of the symbols in the sentence. Like δ, the letter ε represents a space between the variable $f(x)$ and a fixed number L_1. Since the space represented by δ is shrinking, then the related space represented by ε is shrinking too. The overall picture is this: *two points on a curvy line are getting closer together*, and as the horizontal distance between them (δ)

gets smaller, the vertical distance (ε) gets smaller too. It's easy for most of us to imagine those two points coming together like beads on a wire, the distances between them getting smaller and smaller, but in order to describe this process mathematically so it can be used in calculations, one must rely on the intricate relationships between these three different kinds of unknowns.

We move in ways that are just as complicated. When we rise up from the floor in a gentle spiral, the relationship between our head and our feet could not be described in a simple mathematical equation, yet we work it out without trying. I, who thought of myself as a stick of gum, who could not go farther than a single relationship between unknowns, had difficulty making these more complex movements. They were choppy. I found I could think of one part of me moving with another, but could not imagine the entire body working as a whole.

As I gained in my ability to become aware of myself as a whole body, following the gesture of the movement instead of trying to keep track of the component parts, something in my mind specific to mathematics was changing. This three-, four-, even five-dimensionality with which I became conversant as a moving person made clearer the varying levels of relationships of unknowns in these complicated mathematical sentences. Suddenly I could start to see the variables like clock-gears of varying sizes, each moving at its own rate in comparison to the others, all the while generating an overarching idea.

The pieces I had lacked in my mathematical understanding I had lacked in my physical vocabulary as well. By improving my ability to experience and move within space I had discovered for myself a more accessible way to navigate among abstract mathematical concepts.

FUNCTIONAL INTEGRATION

Having improved the quality and complexity of my thinking, it was time to use my improved skills to determine the answer to Moshe's riddle as stated by Carl Ginsburg: How does the mathematical equation $\int f(x)dx=F(x)$ connect with the work we Feldenkrais practitioners do in Awareness Through Movement and Functional Integration lessons? To answer that question, I finally had to master the Fundamental Theorem of Calculus, which I had learned twice before and had never been able to keep in my head. As always, understanding Feldenkrais's work more fully was the key to elucidating the mathematical side of the puzzle.

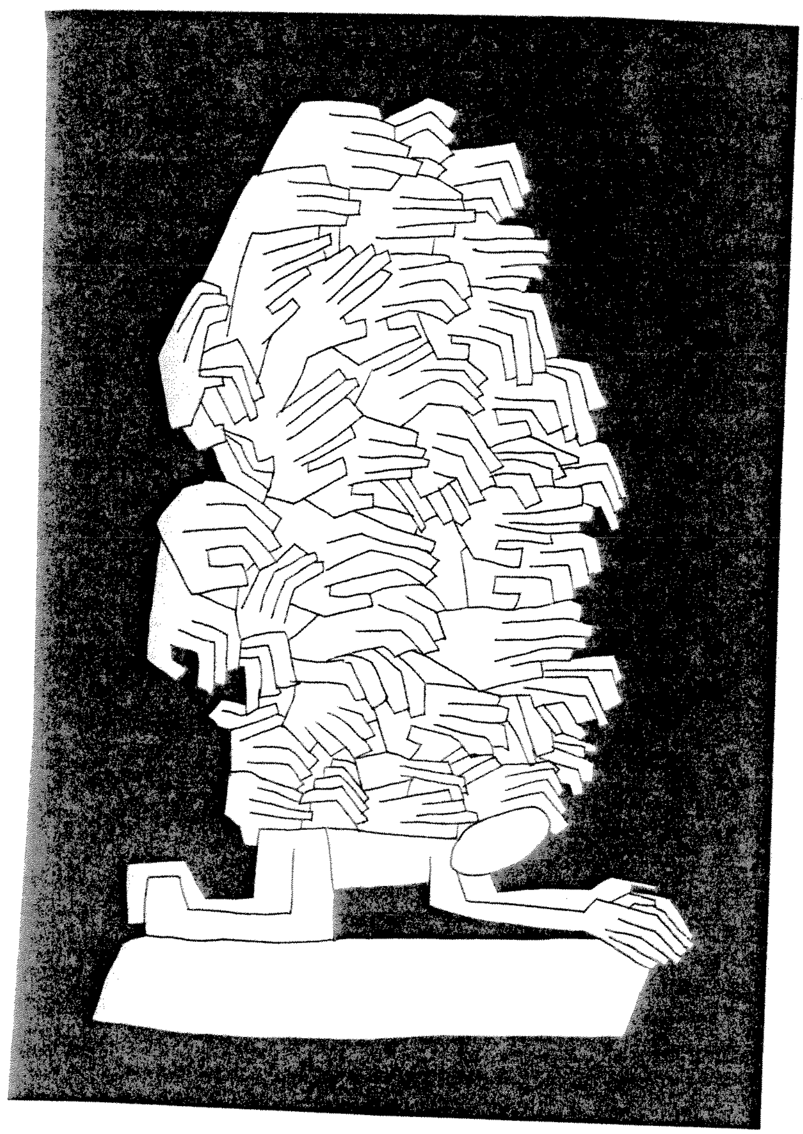
Moshe examined our ingrained ideas about the improvement of a task like "standing." It was generally thought that standing and other such physical acts could be "done correctly if one knew how." If one wanted to learn how to stand "correctly," one had to determine the perfect way to stand, measure every aspect of it, and then adjust oneself to the ideal model, piece by piece. The sum total of this effort would be "proper standing."

Moshe believed that it was too difficult and tedious to try and improve things in this way. Instead, he expanded the *task,* at which you could succeed or fail, into a *function,* which was boundless, which could always be improved a little bit more. He taught people to integrate a higher level of ability into their nervous system and then to compare it with their previous level. In this way, they could see their improvement and over time achieve any level of desired facility in standing without the usual stress of adjusting to a dubious and constraining model.

This approach is analogous to the way in which Newton and Leibniz solved the problem of calculating the area under a curve, which is what the Fundamental Theorem is about. Here is a brief explanation of their process.

It's easy to calculate the area of a rectangle: It's the base times the height. But what if you have a curvy line running a certain distance from left to right, and you want to know the area of the shape under it? Solving this basic problem enables you to determine how a gas will expand, how a planet will act in its orbit, and any number of other things that involve complex relationships.

Before calculus came along, you had to figure out the height of the curve at every point on it, draw a box at each place, and add the area of all those boxes together. But because there are an *infinite* number of points on a piece of a curve you'd be adding boxes forever. Mathematicians had begun to overcome this obstacle with the concept of *limits*, which summarize infinite series of things, but it wasn't always easy to use limits to find the area under a curve segment, and in some cases it was practically impossible.



Newton and Leibniz discovered a better way. Instead of finding the area under the piece of the curve you were looking at, why not take the boundaries away, let the curve go on infinitely, and figure out the area under that? It sounds harder to find the area of an infinitely large shape, but, just as in Feldenkrais, removing the boundaries really makes it easier. When you let the curve go on forever, you no longer have to think about numbers. Instead you can express the pure *relationship* between the curve and the area.

In mathematics, this relationship is called a *function*, and, just as with a human function, it can be differentiated so that you can look at a single aspect of it. First, you examine how the curve acts between any two points. For instance, if it resembles the rounded side of a swimming pool, then as it moves from a in the center to b at the lip, it rises at a faster and faster rate. By moving a and b closer together until they are practically on top of one another, you can actually tell how fast the curve is rising at any *one point*. This is a little like being able to determine how fast a car is going by looking at a snapshot of it.

Newton and Leibniz both understood that differentiation is a reversible procedure, that one can start with that snapshot or single point and work back to a description of the complete curve. Being curious, they went another step and *backwards-differentiated the curve* to see what would happen. Upon doing so, they ended up with a new function that described the *area under the curve*. The difficult calculation of adding an infinite number of boxes was now unnecessary because with reverse differentiation you could solve a much simpler problem and get the same result!

So, if you want to *integrate* a curve, meaning "find the area under a piece of a curvy line," first describe the whole curve as a *function with no boundaries* ($2x$), then *backwards-differentiate* it. What you get is a brand new function (x^2) describing the infinite area under the whole curve. If you plug numbers into the new function where the boundaries of your original curve are (12^2 and 3^2), then subtract the lower number from the higher one, you get the specific area you were looking for ($144-9 = 135$). Expressing space becomes a matter of noticing a difference.

When we differentiate in Feldenkrais, we take a function like seeing, and work with pieces of that function. What happens when you differentiate the act of scanning from the rest of seeing? Or what happens when you look at the relationship of the head to the body when you are looking at something? Can you differentiate your movement so that the eyes move one way while your head moves the other? We use this differentiation to encourage integration of the entire function into the system. Moshe saw a parallel between the symmetry of differentiation/integration in a mathematical function and differentiation/integration of a human function.

He understood that it is difficult to integrate a new idea into the system, but it is relatively easy to differentiate it. We may have trouble connecting the function of the eyes with the movement of the head. Perhaps if we learn to differentiate, moving the head one way and the eyes the other, we may discover a better understanding of the relationship between the two. After spending some time improving this differentiation, we may wish to reverse our thoughts and bring the eyes and the head back together. But this reverse differentiation is the *integration* that was so difficult before!

If instead of thinking of "seeing" as a fixed task, we understand it as a function that can be improved forever, then we have a way of judging our visual acuity that is better than a simple "success/failure" model. When we re-integrate the movement of our eyes with the movement of our head we can compare how well we are coordinating them now as compared to the beginning of a lesson. Our ability to gauge our improvement provides us with an awareness of our function that we lacked before.

In mathematics, Leibniz and Newton made possible what had been impossible by showing differentiation and integration to be different aspects of the same idea. Similarly Feldenkrais, clearly inspired by the dual nature of awareness, discovered that taking a human function apart requires the same thought process as integrating that function into our behavior. The result? Expressing *space* becomes a matter of noticing a *difference*, the impossible becomes possible, and Moshe's statement that his work can be represented by the expression $\int f(x)dx=F(x)$ proves to be correct.

CONCLUSION

It is rather a strange thing that I should have been so captivated by the idea that a Method which I explored to eliminate the pain in my hands could improve my math skills. There was something in my desire to understand mathematics that I could not see, a deeper desire for which mathematics-ability was merely the outward manifestation. The quest to solve a problem which I could identify instead led me through improvements which I was unaware I needed.

In the Feldenkrais Method we avoid concentrating on the details of a client's dilemma. We learn instead to attain a state where we can perceive a whole person at once. In order to guide a person toward improvement in this state, we focus on details in their pattern while still maintaining the view of the whole of them, the context surrounding them, our relationship to them, the environment in which we are working, and any other information that relates to who they are. Learning to focus while maintaining a broad field of perception is one of the essential skills of the Feldenkrais practitioner.

The true value of my experience as a Feldenkrais trainee was to hone this skill. Unbeknownst to me, this is the precise ability that a mathematician uses on a purely intellectual level to comprehend proofs and problems. Overcoming some of the physical limitations to this kind of perception, I began to experience the world in a new way, learning to see details while relating them to a larger context, understanding myself as a small piece of a larger world, learning how I could make my way through that world and relate with it. Because of my focus on mathematics, I was able to apply my improving skills specifically to that discipline and understand the path I had taken to reach my own improvement.

As a scientist, Feldenkrais undoubtedly made use of this type of perception early on, but unlike many of his colleagues, he endeavored to understand how he was able to think in the way he did. Surely the model of integration, where one is able to focus on a particular section of a curve by maintaining the importance of the overall relationship of the function, served as an inspiration to him.

I have high hopes for the use of this Method in ways that relate directly to intellectual improvement. Many people remain convinced that their mental capacity, like their physical capacity, is limited, and that they are suited for certain kinds of thinking only. As our work can open up possibilities for the athlete or the performer, so it can for the thinker as well. The interrelationship between the body and the mind, just like the long-hidden relationship between integration and differentiation, can be seen as being whole and inseparable.