

## *A Fear of Physics: Interdisciplinary Learning in Grade Four*

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In this autobiographical study, I investigate Fritjof Capra's assertion that seemingly diverse elements share commonalities and that the arts are best suited to visualizing and mapping those commonalities. Looking back at myself as a pre-service teacher, I trace interdependence across disciplines in curriculum pitched at the junior level. Through narrative and reflective modes, I identify transitional moments in a Grade 4 classroom that triggered both my students' and my self-expression and nurtured diversity in our learning community. I seek as well to discern myself as an open, self-organizing system that initially operates at a distance from equilibrium in the teaching process, only to later create sound and creative learning from that point of instability. I also examine how the facet of self that co-creates with students encourages my development as a teacher and writer. Finally, I address the overarching question that underlies a systemic analysis of learning and the complexity theory that incorporates such an analysis: How do multiple pedagogies and modes of expression weave together into a complex whole?

### *Mid-winter in St. Catharines, Ontario, Grapeview Public School*

*3:40 p.m., and the Grade 4 class has emptied. The first day of my second teaching block is nearly over, and I am seated next to my associate, Mrs. N. As a student teacher at Brock University's Faculty of Education, I have been keen to soak in everything. I wonder how I will live up to Mrs. N's standards and professionalism after watching her move in sync from one activity to the next. I think of a phrase I have heard at the faculty: she makes it look so easy. Mrs. N. takes out her planning book and gently informs me of the unit I will teach over the next four weeks. It is to be integrated with a focus on physical science – a unit on density. My heart pounds red alert.*

*"Physics", I repeat with a tremor in my voice. "Density?"*

*"Yes. Students will be experimenting with density, hypothesizing, working hands-on... you seem upset, Carol." Her tone is caring but carries judgment.*

*I lower my face, recovering a high-school memory of shame.*

*"I didn't do well in science, in physics."*

*"This is Grade 4, remember; we're introducing them to the concepts." Mrs. N. leans in closer to me. I look up but avoid her eyes. She braces her shoulders. I sense that she is extending herself – that her patience is deliberate.*

*I don't answer. This may be Grade 4, and only an introduction to density, but I remember the Grade 10 science lab at our high school, with the big block counter at the head of the class. It is 1969; I am fourteen years old and have built a sturdy brick wall between the sciences and the arts, a wall without cracks. I see Mr. McKay, as he enters from a door on the left adjoining the science room. Aside from the pasty colour of his complexion, he is a portrait in black (a candidate for a mausoleum). He is dressed in a dark suit, his black-rimmed glasses tip slightly on one side, and his dark cropped hair is smeared in gel. His walk is shaky, and his speech slurred, but even if he is intermittently clear (and the alcohol we smell daily on his breath has not been consumed), the concepts are anything but clear to me. Mathematical equations loom galactic. Diagrams in our texts denote spatial relationships that are untranslatable to me. I stare at the open page of my text while a printed procession of lines, semi-circles and numbers march by; some numbers are whole and some are fractions, some appear in superscript as part of a compact formula, while others hide like booby traps in paragraphs, never-ending paragraphs whose problems combust in my brain. As for experiential learning, I fall behind my peers who are absorbed in the experiments. What hope do I have of uncovering the mystery, order and grace that physics confers on them?*

*"It's not science at an advanced level." I smile, rationalizing my way out of a bout of student-teacher anxiety. But privately, I am computing: Mrs. N. will write one of three reports prospective employers will read.*

*Mrs. N. stands up. She looks relieved. "The unit will come with planning. One thing to keep in mind at the start, hypothesis is important", she explains. "Students should understand that a hypothesis doesn't need to be accurate, that they will compare their hypotheses to the result of their collaborative experiments. Good luck, Carol."*

### Postscript to narrative

I wanted in this brief narrative to relay the vulnerability I felt as a pre-service arts-based teacher. At the outset, I was at a distance from "equilibrium," in need of interplay between the structure of the classroom and my associate teacher's expectations, and the change and challenge ahead of me. In Capra's synthesis of complex systems, he draws on Ilya Prigogine's theory of dissipative structure to characterize this stage, which while unpredictable and indeterminate, can lead to the novel and the emergence of order and creativity (Capra, 2002). Did I become a science teacher once I threw myself into this unit? No, I won't smooth over the narrative from this chapter of my teaching life. But in opening up to the new experience, in implementing the unit, I encountered new learning. At this point, I will begin the process of describing and storying moments, which when taken together, form a story that will map this evolution in me (Elbaz, 2002).

#### *The Unit: "Experimenters at Work"*

Along with my students, I grew into the unit, propelled by the storytelling that lay within the scientific discipline. Science was not to be delivered in a linear design but as part of a network. The arts made their way into that network, to my clear advantage. As Capra suggested they would, the arts most effectively helped students recognize and express the very patterns that emerged in this unit as everyday physical objects were transformed by the power of density (Capra, 1999).

Storytelling, the first art form, came in one of the early lessons from Ancient Greece, a story about the experimenter, Archimedes, who had been called upon by King Hiero to solve a dilemma concerning the quantity of gold in his crown. This was a tale I could tell about mass, volume and a tub of water, its "meaning emerging from a wider cultural matrix" (Kyburz, 2004, p. 510).

Incorporating language studies along with science, I also read chapters from Harriet Ziefert's 1988 story, "Egg Drop Day". In this story, a class of ten Grade 4 students was

presented with a challenge. Each student was to wrap a raw egg well enough so that when he or she dropped it out of the window, the egg would not break. Their fictional teacher, Mr. Rose, provided an array of materials students could use to wrap their eggs: string, rubber bands, newspaper, wool, cotton and foam rubber, tape, salt and clay. He left the students to discover what and how much material they would need and how they would use it. As the story progressed, competitiveness turned to quiet, independent designing of unique solutions.

My Grade 4 students related well to the fictional students of Mr. Rose's class. In fact, one girl took the story into her own hands, wrapping eggs in various materials and dropping them out of her bedroom window. (Her parents later told this to me). This girl's exploration defines interdisciplinarity and its inseparable companion: inquiry learning. Harriet Ziefert's story linked the science discipline in the classroom to the questions and concerns of my young student, who wanted to understand a small reality in the world, a phenomena outside the classroom. Consequently, she puzzled over the questions, sought her own answers, and tested the applications using her imagination, science and tools (Tchudi, 1981).

Materials and methods of inquiry, which were borrowed from the English discipline, threw light on and developed students' understanding in the science discipline. I could draw on pedagogies that mutually reinforced one another by teaching this story in a density unit. Reading strategies were strengthened. I introduced students to scientific terms, asked them to listen for and recognize cause and effect relationships, to draw connections between themselves and the fictional students (as the girl had surely done), to evaluate the fictional teacher and science learning in the story, and to rewrite and edit their journal responses. Students were engaged in composition that was informed by science (Kyburz, 2004).

Encouraged by these stories, I too could welcome introductory concepts about density and take the next step. In groups, through hands-on experiments, students worked in a compare/contrastive mode, first with oil and water. They then continued by explaining why some materials were more compact than others, why some objects floated better than others; and they examined the densities of several coloured liquids with different quantities of salt. Students' understanding of density deepened and became more concrete with every hypothesis and recorded experiment. Through their active learning, science began to animate me. I shifted to higher competency in a unit Donald Schön might well have characterized as "an indeterminate zone of practice" fraught, as it was for me with "uncertainty and value conflict" (Schön, 1987, pp. 6, 18). I began to trust that I could teach this unit, building my confidence by exploring "connectedness in a wider arena" (Beattie, 2004, p. 101). In an audio-recording of a seminar, Capra speaks of trusting his creativity after discovering themes in reading material with which he could align himself (2004). Bound in varied disciplines, the narratives provided a science framework I could find meaningful, an "experience of context" (Capra, 2004). Facts about density were no longer foreign symbols on a page; the stories were keys to open meaning, both for myself and my students.

I have referred to experiments being recorded. Students wrote their first experiments and created written discourse using an organizational text structure. Citing Judith Schickendanz, Gloria Houston (2004) points to the development of discrete reading and writing skills that come about due to familiarity with text structures. Firstly, the familiarity aids comprehension because the reader/listener has an organizational scheme with which to think about the content of the reading. The writer then places the pattern within that scheme to further discern meaning. The pattern for my Grade 4 class came in headings: Question, Hypothesis, Materials, Procedures, Results, Conclusion. Using transparencies, I modeled the steps and sequence, creating examples students were to apply when writing about their scientific process. I asked that students write

consistently in present tense verbs under the headings to describe the content. This created balance and made the writing more sequential for the audience.

In this problem-solving activity, students planned and set goals. The headings became “cues for content retrieval” (Bereiter & Scardamalia, 1987, p. 7). At the outset of the experiment, students as novice science writers generated appropriate content items in their group note-taking, graduating into text that involved “multi-level data structure” (Beaugrande, cited in Bereiter & Scardamalia, 1987, p. 15). They imparted the facts of their experiment, often revising and reformulating, ultimately transforming their knowledge. Concurrently, students interacted socially in groups while working interdependently to complete the task in the social space of the classroom (Bazerman, 1994). Each student had an independent role and task, ranging from runner (to acquire materials), to recorder (to write) and leader (to guide the others, time-keep or keep on track). The rhetorical purpose controlled the text and the types of strategies employed so that students could achieve their purpose and adapt the text for the reader.

To reinforce this writing aspect of the unit, a musical component emerged that provided a “spontaneous shift in direction” (hooks as quoted in Kyburz, 2004, p. 518). I was about to discover through a musical chant, and the subsequent integration of disciplines (classical music appreciation, visual arts and drama), the “similarities between phenomena at different levels of scale” (Capra, 1999, pp. 4-5). In designing this integrated curriculum, I would create a “multi-sensory learning environment” where students were free to make mistakes as they were encouraged to hypothesize, experiment, create, and learn collaboratively (Capra, 1997, p. 9).

*I rested my elbow on an edge of the Olympic-sized pool at Brock University and looked across the water. There were plenty of swimmers that evening, but I had ample space in my lane. I took a deep breath before launching into another lap. Physical activity always helped the flow of ideas. I had been thinking about the unit – couldn’t let go of it. All the students were set to write experiments; those identified with special needs had templates with prepared headings while the other students were to recall the headings and produce their structured text independently. I anticipated that students were encountering something new, and I wanted to modify and enliven their new conceptual framework in an engaging way, thereby “relying” as Michael Polanyi suggests, both on my “anticipations and my capacity to re-adapt to a novel situation” (1962, p. 103). Capra, too, partners our highly adaptive brains with our ability to adapt to, interact with, and create in our environments (Capra, 1996). I immersed my body in the sealed-off quiet of an aquatic world, a quiet I broke when I lifted my head out to breathe. The rhythm of my strokes and the forward/backward glide of swimming energized me; in my head, I started singing a chant with echo phrases.*

*Can you name the six parts?*

*Can you name the six parts?*

*Of an experiment?*

*Of an experiment?*

*Q H M P R C*

*Q H M P R C*

*What does that stand for?*

*What does that stand for?*

*Question – hypothesis*

*Question – hypothesis*

*Materials – procedure*

*Materials – procedure*

*Results – conclusion*

*Results – conclusion*

*After rehearsing the chant, I laminated coloured flash cards to prepare for class. The next morning, I sang the chant solo to introduce it before modeling choral techniques with the students i.e., singing unison/solo-chorus response. I then added the flash cards, which I handed out randomly. Students holding the cards were to jump up in rhythm and flash their cards when their heading came up. Simple enough – hardly a composition...yet...I count this teaching experience as transitional, as evocative. Students quickly took to the chant and owned it. With some negotiation on my part, the chant re-emerged at peak moments during the school day, times when the students needed a dose of patience: before recess, lunch, at dismissal, when they were raring to leave but were asked to stay seated. Chant-in-hand, they didn't fidget or look longingly at the clock; there was a lively expectancy in the room even as the students stayed in place. A student's voice would begin: "Can you name the six parts?" I stood back and watched as students assumed responsibility for their own learning. The chant was meaningful to my Grade 4 students because of the personal context from which it was derived; students were writing those headings during the day and could now declare this knowledge outright like an anthem. I had found a balance between "designed structure" which enabled the class to operate purposefully day-to-day and "emergent structure" which became the "expressions of the collective creativity" of the class (Capra, 1997, p. 8).*

Accessing my personal and practical knowledge, learning also occurred because of the routines and rhythms I accessed and because students abided by and respected the consistency that those rhythms and routines brought (Beattie, 1995b). In my leadership role, I asserted authority through music, and what transpired was collaborative. Here I use the word authority not as an "abstract notion of individual autonomy" but in "concert with the relationships it articulates and effectuates" (Britzman, 1991, p. 18).

In turn, while chanting and singing, students self-organized as a community of learners, interacting with a classroom environment that did not overly constrain their behavior, but afforded them the opportunity to reach out as nine-year-old engaged kids for those qualities of independence and resourcefulness in themselves. I understood classroom management, then, "in the context of respectful relationships" and not as a matter of control (Beattie, 1995a, p. 18). Moreover, I was constructing an image of myself as a teacher that didn't erase a central part of who I was before I was a teacher, that didn't fragment but incorporated my professional musical past and present selves. And I extend Freema Elbaz's (1983) definition of image as the coalescence of personal values about and purposes for teaching to Jean Clandinin's (1985) conception of the term, as one coloured with its emotional and moral dimensions of experience. As I judge the standard of my practice in that Grade 4 class, I do so as part of a continuum of experience. I view practice, therefore, as "process and becoming", as I change and transform my teaching circumstances (Britzman, 1991, p. 239).

I had not anticipated successfully matching the simple melody and rhythm of the chant, and the choral singing of it, to the discipline of science. Playing what Peter Elbow (1973/1998, p. xxii) calls the "believing game," I continued to test out, and play with, ideas beyond what I could imagine. Specifically, I further integrated science with classical music and visual arts in the unit. Prompted by a wonderful suggestion from the music instructor at Brock University, I linked concepts of texture, thickness of sound in orchestral music, to the scientific concept of density. While Sergei Rachmaninov's "Rhapsody on a Theme of Paganini, Op. 43" played, students listened to the piece three times; first, to appreciate its heart-breaking beauty; next, to identify and name instruments they heard in the orchestration, and finally, sketching the movement of the music and outlining densities with coloured pencils on cartridge paper. Gradually, they represented sound through colour with their hands and tools. Interacting with both music and visual arts, students were heightening their musical and visual arts consciousness, constructing, expanding, and deepening meaning in different forms of representation (Eisner, 1994). They worked at their desks, on the floor, on counter tops,

experimenting with colour, shade, texture, creating a backdrop and finally, entitling their individual and diverse works. If there once had been chaos in the classroom, now there was order in the chaos and the students completed the task “by making the order visible” (Capra, 2004). Novelty had been generated that was different from the materials out of which it emerged (Capra, 2002).

The movement of Rachmaninov’s composition and the students’ multiple interpretations of the texture and changes in his music were displayed on the classroom walls. I scanned the classroom to take in resplendent waves of colour, pyramids, small bars and geometric shapes pressed down hard on the page – all this individuality signifying something of the passion of Russian classical music. Transacting with the learning environment, then, each Grade 4 student, whom Capra refers to as a living learning organism, responded diversely as an “autopoietic self” to the activity, and learned, developed, and changed structurally according to his or her own non-linear nature. This self (“auto”) - making (“poiesis”<sup>1</sup>) capacity is universal to all learning-living systems (Maturana & Varela cited in Capra, 1996, p. 97). With the new experience of connecting science, music, and visual art came the possibility of creating new pathways in students’ brains and the creation of novelty and creativity (Capra, 1996, 2002). The form and content of the Rachmaninov piece was reconstructed and transformed by my Grade 4 students into collective, diverse visual and aesthetic works on the papers that hung on those walls.

Guided by my associate teacher, our last interdisciplinary activity brought drama to the forefront. After due process, inclusive of research, speech-writing, and rehearsal, the preparation of cue cards and the setting up of video cameras, students presented their choice of researcher / experimenter in-role. Students were engaged body, voice, spirit and mind as they transformed and re-enacted their versions, their interpreted personas of luminaries like Thomas Edison, the Wright brothers, Marie Curie and Louis Pasteur. Some students assumed foreign accents; many wore props as they stood before the cameras retelling stories at different stages of their researcher’s life. The dramatic culminating activity allowed for students’ full self-expression.

Each part of the density unit functioned as a meaningful subsidiary to the whole, thereby sustaining the whole as Polanyi (1962) suggests in a Capraesque fashion. My students and I were presented with the “multiplicative effect” of integrated pedagogies (Newell, 2001, p. 115). Though these disciplines may have been grounded in different perspectives and epistemologies, my students were enriched by their discovery of interweaving patterns between *seemingly* diverse elements. Through exploring the links between relevant disciplines, my students and I constructed a more complex and whole understanding of the phenomena of density.

*Reflecting back on the unit – complexity theory coalesces with practice*

The practice teaching sessions ended, summer was on, but the lessons I learned in practice teaching echoed in me. I had begun teaching the Grade 4 class in self-doubt, operating far from equilibrium as is true for learners. Yet, as a “dissipative structure” remaining open to the flow and receipt of the energy from outside, I “not only maintain[ed myself] but evolved through positive feedback loops” (Prigogine as quoted in Capra, 1996, p. 89). The feedback loops in this chapter of my life hummed as multi-faceted, causally-connected networks of activity. With feedback from my teaching associate, I designed the density unit and evolved along with my students in my internalization of interdisciplinary learning.

The evocative moments I experienced in this chapter of my teaching/writing life came in “small sudden insights” (Capra, 2002, p. 119). They were triggered by my sense

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<sup>1</sup> *Poiesis* shares the same Greek root as the word “poetry” which means making (Capra 1996, 97)

of a need for writing reinforcement, by physical activity, through the modeling and teaching of the chant, and by the receptivity of my students. Their occurrence had much to do with the positive way my students responded to my teaching of a piece of writing tailored to their needs. The transitional moments had to do with my growth, and my facilitative role as a teacher and partner in learning with my students. These moments entered like unexpected guests into my home, a home whose rooms were lit and whose windows were swung open. They came, not in a fanfare of horns and trumpets, but as a significant part of the daily stream of activity, the "web of life" as Capra (1996) adeptly entitled his book.

Finally, I maintain that the Grade 4 science/arts classroom became a community, an "ecosystem of learning" (Capra, 1999). While I have noted the self-making capacity of my students and myself as a teacher, I emphasize this inclusive dimension. In our community/ecosystem, my students depended on one another in a rich multi-sensory learning environment where they "cyclically exchanged information through feedback loops" (Capra, 1999, p. 9) and generated creativity. Leadership in this context was systemic, shared, and responsibility extended to the capacity of the whole. My "power of authority empowered my students" (Capra, 2002, p. 122).

Like the natural environment with its many species and overlapping ecological functions, the Grade 4 classroom became a resilient ecosystem because the variety of activities cultivated the diversity of my students (Capra, 1996). Multiple intelligences were activated through both the arts and science.

I value this ecosystem as the ideal learning culture, one I have not consistently enacted since my pre-service teaching days, as I have moved from English language arts at the secondary level to university teaching of future teacher educators. The flux of reality that characterizes teaching and learning can sometimes render the experience tenuous. Nevertheless, after reading Capra and shaping my philosophy around his work, I commit myself to creating ecosystems that sustain and nurture learning communities in my classrooms, in essence, to recreating the dynamic quality of learning that emerged among those Grade 4 interdisciplinary learners years ago.

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