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THE COMPLEXITY OF REFORM EFFORTS IN SCIENCE CURRICULUM
AND INSTRUCTION: A CASE STUDY OF THE ILLINOIS MATHEMATICS
AND SCIENCE ACADEMY CHEMISTRY TEACHER

BY

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DISSERTATION

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Abstract

This study explores how teacher-initiated site-based reform in a specialized STEM school is conceptualized and enacted, how and why curriculum reform ideas change in the process of enactment, what qualities of teacher agency are entailed, how these qualities are acquired, interplayed, become generative, and/or are influenced to effect different curriculum reform outcomes, and how different conditions support and further teacher agency to make a more defensible curriculum.

In a critical case study of a highly experienced and qualified science teacher, I follow a teacher who initiated efforts to reform the advanced chemistry curriculum. This teacher wanted to make the curriculum more inquiry-based and less like the Advanced Placement—a College Board curriculum and examination. I conducted a critical narrative inquiry into aspects of his teacher agency in this highly contested sociocultural and sociopolitical context before, during, and after one year of curriculum change. I tracked the process using interviews with the teacher, colleagues, students, a student's parent, and school administrators, lesson observations, and artifacts such as curriculum materials and school brochures.

By uncovering conflicts and contradictions in various actors' standpoints, I analyze tensions and coping strategies with aspects of teacher agency simultaneously enabled and circumscribed by multiple factors and forces of this specialized STEM (science, technology, engineering, and mathematics) schooling structure. The teacher's initial curriculum change ideas became moderated, adjusted, and mediated. The findings of this study may be insightful to educators and legislators interested in specialized schooling and teacher empowerment.

For My Family

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Summary of Symbols

(aq)	Aqueous state
[x]	Concentration of x
g	Grams; a unit of mass measurement
g/mol	Grams per mole; a unit of quantity measurement
K_a	The acid dissociation constant; a measure of the extent of acid dissociation
L	Liters; a unit of volume measurement
M	Molarity (grams per mole); a unit of quantity measurement
ml	Millimeters; a unit of volume measurement
mmol	Millimoles
pH	Negative logarithm to the base 10 of the concentration of hydrogen ions; a measure of the acidity of a solution
pK_a	Negative logarithm to the base 10 of K_a
pK_1 (pK_2)	Negative logarithm to the base 10 of K_1 , the first (second) acid dissociation constant of an acid

Chapter 1

Introduction

“Increasingly, teaching methods, texts, tests, and outcomes are being taken out of the hands of the people who must put them into practice.”

Apple and Teitelbaum (1986, p. 179)

This is a critical case study of a specialized high school science teacher who initiated and led the curriculum reform process in his school, the Illinois Mathematics and Science Academy (IMSA), located in Aurora, Illinois, in the United States. This teacher, Dr Darren Daley (a pseudonym), proposed and revised the advanced chemistry course making it more inquiry-based. He perceived the existing curriculum to be similar to Advanced Placement (AP)—a course of study culminating in a College Board examination which gives college credits. Having taught AP for about seven years in his previous school, Daley found AP to be too structured and overloaded with content rendering direct teaching as the most efficient content delivery mode. This contradicted his beliefs on teaching and learning, especially for gifted and academically talented students at IMSA.

Daley graduated with a doctoral degree from a large midwestern university and was trained as a biochemist. He had 17 years of experience teaching chemistry. After 13 years of teaching in a Chicago suburban high school, he joined IMSA to lead the advanced chemistry course for mostly eleventh graders. After teaching the syllabus previously written by the retired teacher and his team, Daley found the curriculum resembling AP in structure and content and lacking in laboratory engagement. In 2008, he proposed his idea of curriculum change to the principal. He envisioned students doing open inquiry, actively engaging in learning through laboratory activities. In Summer

2009, he led a team of chemistry teachers to deliberate and revise the two-semester advanced chemistry curriculum. They enacted the revised curriculum in Fall 2009 and Spring 2010.

Daley claims his vision for curriculum change is aligned to his school's mission to become the "world's leading teaching and learning laboratory for imagination and inquiry" (IMSA, 2009a). IMSA, an internationally recognized high school, offers a rich context to understanding inquiry curriculum reform efforts because of its reputation for excellent science teaching, the credentials of its teachers, and a professional environment encouraging and enabling individual teacher efforts to rewrite curriculum for their departments. While many high-performing U.S. high schools offer AP as their college preparatory program (Schneider, 2009), highly qualified IMSA teachers—all with a minimum of Master's degree, 52% holding doctoral degrees, 23% certified by the National Board of Professional Teaching Standards (IMSA Quick Facts, October 2009), and an average of 15 years of teaching experience—design, plan, and write their own curriculum.

Daley's agency to revise the curriculum, however, has a paradoxical quality with high demands politically as well as pedagogically—it calls for an elevated degree of rationalization and accountability in every decision made. Daley must manage tensions arising from contradictions and conflicts between non-arbitrary and complex socioeconomic, sociocultural and sociopolitical factors, forces, and asymmetrical power relations. These problems constrain his professional agency in enacting his teacher role and identity. In other words, Daley is respected as the subject expert in chemistry, but he is not completely autonomous in his curriculum work and teaching. Different forms of

limiting and enabling power are present, penetrating different conduits, and operating in different ways. These forces play into his curriculum work and teaching holding him accountable to his curriculum decisions and actions.

Research Lens and Questions

Drawing on my personal experience as a chemistry teacher who taught in a Singapore specialized mathematics and science school modeled after IMSA to a certain extent, I conduct this study beginning with broad and extensive interests and questions on science curriculum making for gifted or academically talented students in such specialized schools divorced from the mainstream standardized curriculum and testing. Then I gradually narrow my focus to examining the nature of this teacher's agency as embedded in this contextualized and historicized structure of curriculum change. This focus progressively emerges from observing, listening, thinking, and understanding the complexities and challenges in the curriculum change process as embedded in a highly contested space, and subsequently grounds my research design, analysis, discussions, and self-reflections.

The two sets of research questions I want to address in this study are:

1. How do Daley's ideas of science inquiry curriculum and curriculum reform change over time as he initiates, deliberates, enacts, and reflects on curriculum change and teaching in the context of a specialized STEM school?
2. What are some qualities of Daley's teacher agency? How do factors promoting or inhibiting Daley's agency to do curriculum reform work in this structure play out to shape curriculum making, the revised curriculum, and teaching?

In valuing Daley as the initiator and catalyst of curriculum change, I center him as the case participant from whom I seek to understand the nature of teacher agency in curriculum reform and teaching in the context of a specialized school with a focus in

mathematics and science. For example, Daley's envisioning of this revised curriculum reflects his theories, beliefs, and philosophies about science, chemistry, teaching, learning, IMSA students, and IMSA. I value his constructed understanding of inquiry as grounded in his knowledge, skills, and experiences in science teaching and doctoral research by examining how he translates his understandings and envisioning into his curriculum plans and enactment. This personal knowledge in dealing with change can be understood through situated storied experiences and not general or grand theories of teachers' roles in curriculum reform or inquiry-based curriculum. This approach differs from those imposing external mandates or experts' views on teachers, expecting faithful implementation of science reform prepackaged as teacher-proof inquiry curriculum. Such curriculum materials are designed by research groups intended to 'help teachers teach better', but the approach relegates teachers' professional roles to curriculum implementers, disseminators, or receivers rather than curriculum initiators, leaders, makers, developers, reformers, or planners. It is not surprising such research conclude teachers to be ineffective in using the curriculum materials with outcomes less desirable than expected. The root of the problem, however, is that teachers could not adaptively engage with the materials, especially when they are not consulted on students' needs (Olson, 1982). Hence, the grounded approach I am taking in this study disrupts conventional approaches relying on the national standards and frameworks to examine teachers' efficacy in science reform.

Research *about* teacher-initiated curriculum reform in specialized STEM schools involves complex, in-depth investigation into visible and non-visible elements embedded within the complexities shaping how a teacher engages with curriculum change. In this

study, I apply a critical lens to inquire into issues and problems circumscribing Daley's teacher agency in the structure of IMSA. Critical study in education is associated with emancipatory practices to liberate teachers from the debilitating practices of schools (Eisner, 1985). Teachers, such as Daley, can be said to have emancipatory interests if they focus on engaging students as active creators of knowledge rather than passive receivers of knowledge (Grundy, 1987). I track Daley as he lives out the process of curriculum reform, examining the underlying covert assumptions and tacit values of the enterprise of specialized schooling in the social text. I critically examine what forms of agency Daley has in his curriculum reform work, how he is empowered with agency, and to what extent he is able to exercise his agency.

In this critical narrative inquiry, I examine the quality of teacher agency in connection with the historical, socioeconomic, sociopolitical, and sociocultural factors and forces which penetrate decisions concerning what knowledge is taught, how it is taught, and why it is taught. Hence, there is interplay of macroanalysis and microanalysis of broad factors and forces interacting with decisions and actions at the local level of curriculum making and teaching. When Daley claims his identity as the lead advanced chemistry IMSA teacher and curriculum reformer, he undergoes a transformative process to become a self-empowered agent. I examine how Daley exercises his teacher agency to (re)produce schema and practices (Tobin, 2005), applying his beliefs, theories, knowledge, skills, and capital to access, appropriate, and engage human (e.g., students and colleagues), material (e.g., space, time, physical resources and curriculum materials), and symbolic resources (e.g., power relations, power, status, social networks, and qualifications) in constructing an inquiry curriculum.

However, curriculum goals can become contradicted and conflicted when intertwined in a complex web of historical, sociopolitical, socioeconomic, sociocultural, and institutional ideologies representing a *heteroglossic* system (Bakhtin, 1981) of power relations working simultaneously to empower and disempower Daley to do his reform work. These symbolic factors, established from positions of power in the institutional regime become shaping effects and frames to regulate and distort the professional sphere and teacher agency. As such, Daley's ideas for revised curriculum change through the conceptualization to enactment process as he balances his curricular ideologies and manages different factors constraining or frustrating curriculum change. The meanings of curriculum reform and inquiry-based curriculum are fluid and dynamic as shaped by multifarious viewpoints and contextual features.

Tensions—intangible, ambiguous, hidden, vague, direct, and indirect—can play out in Daley's curriculum work and teaching as dilemmas, contradictions, ironies, and distortions. I examine these changes and how tensions arise as his ideas deviate from his ideal and he seeks means and ways to manage different constraining factors in his curriculum reform efforts. I believe it is important to examine tensions teachers experience in carrying out such work because of its effects on their practice (Olson, 1981). This tension, as opposed to being negative and restraining, can become the productive impetus to rethink, reexamine, and devise new and/or better ways of working with obstacles and developing greater teacher agency with wiser and stronger curricular competence. I attempt here to examine relationally or structurally how Daley resists obstacles, navigates his curriculum reform work and teaching as these factors interplay with his visions and plans. His resistances to norms and strategies in managing these

tensions are valued as constitutive of teacher agency. Further, by engaging Daley to be reflexive as he carries out his work and involving him in this research as a primary case subject with a critical voice, I offer a space enabling praxis. He can become more critical of issues and problems circumscribing his professional agency and structure and find ways to overcome them within his means and situated context.

The Illinois Mathematics and Science Academy

Currently there are over 100 specialized schools in the United States forming an alliance as members of the National Consortium of Specialized Secondary Schools for Mathematics, Science and Technology (NCSSSMST). These schools are closely linked to STEM (Science Technology, Engineering, and Mathematics) education goals as part of the *America COMPETES* (Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science) Act signed into law by former President George W. Bush in 2007 to promote a citizenry well versed in these fields. This political, as well as educative goal, was in response to a government report, *A Nation at Risk* (National Commission on Excellence in Education [NCEE], 1983), cautioning the extent to which schools in the U.S. appeared to have fallen behind the rest of the world. This report subsequently became a powerful political instrument in driving educational reform.

IMSA is in part a manifestation of these ideologies.

IMSA was established in 1985 by the Illinois General Assembly as part of the State's comprehensive education reform package to address this critical need for citizens highly skilled in STEM fields. It is an independent state agency funded by the Illinois legislature under the Illinois Board of Higher Education and governed by an appointed Board of Trustees. IMSA is a three-year tuition-free boarding school for Grade 10–12

students. In 2009–2010, the student demographics consisted of 650 students from urban, suburban, and rural communities in Illinois. 51.5% were male, 48.5% were female—40.5% White or Non-Hispanics, 40.8% Asian/Pacific Islander, 8.3% African American, 5.3% Hispanic/Latino, 2.5% Multiracial; and 2.5% Other ethnicities (IMSA, 2009b). In 2009, the average scores of various college entrance examinations of IMSA tenth graders were: 31.5 for ACT (American College Testing, state average was 20.8), 666 for Critical reading (national average was college-bound seniors was 501), 721 for SAT (Scholastic Assessment Test) Math (national average was 515), and 663 for Writing (national average was 493). The 2008–2009 AP Chemistry score taken by 128 students was 3.01 (maximum score of 5). In addition to mathematics and science, the courses offered include English literature, film studies, gender studies, history, art, microeconomics, and foreign language. IMSA is not held accountable through statewide high stakes testing. Rather, it is charged to “offer a uniquely challenging education for students talented in the areas of mathematics and science”, and “to serve the school system of the State as a catalyst and laboratory for the advancement of teaching [and] stimulate further excellence for all Illinois Schools in mathematics and science” (IMSA Executive Report, August 1999)

Theoretical Framework

The opening quotation by Apple and Teitelbaum (1986) projects concerns over teachers losing control of their profession as they become alienated from authentic curriculum work and teaching, such that their accumulated years of knowledge and skills atrophy over time. Deskilling might occur as they become accustomed to implementing and executing prepared lesson plans using the same instructional methods repeatedly

without adaptation or change. Deskilling works its way through the structure in insidious ways such as making teachers feel ‘burnout’—the ultimate step towards unsuccessful attempts to cope with the negative outcomes of stress (Farber, 1981). This in part, results from managing endless peripheral non-teaching related tasks that are said to be part of their professional responsibility, loading excessive expectations and pressure to focus on testing related activities, requiring teachers to demonstrate extracurricular capabilities. Teachers are diverted from doing authentic curriculum work such as revising curriculum materials and designing new activities that are adaptive to different students’ needs and learning capabilities. Their effectiveness in teaching and curriculum making are reduced (Duschl, 1990), making it easier for external controllers such as legislators, curriculum planners, and commercial curriculum producers to infiltrate their professional sphere to impose their ideologies on the school curriculum and teaching. Nonetheless, teachers have grounded knowledge of students’ needs and capacities at the local level, and broader views of educational goals and structural factors that interplay to constrain or facilitate change. If curriculum reform were to happen effectively, the planning, design, enactment—a more appropriate word describing teachers’ work conducted with agency rather than “implementation” which suggests the execution of actions according to plans—and evaluation of curriculum and teaching must be rooted in the efforts of teachers as they remain the key to what science education will be (Stake & Easley, 1978).

Teacher resistance. Teachers will never have their curricular power removed because they are the ones with direct access to students; they act as the knowledge brokers deciding what to teach and how to teach. It is thus more accurate to describe teacher agency as “mediated” rather than “lost” or “usurped” as teachers do resist

(Bullough, Gitlin, & Goldstein, 1984, Hargreaves, 1982; Giroux, 2001; Lasky, 2005).

Bullough et al. (1984) said,

As [teacher] role becomes less taken-for-granted, less ideologically embedded, and as teachers begin to evaluate how they might create more humane and educative life spaces within schools, resistance becomes those acts that press up against role boundaries (p. 342)

In the 1970s, Stake and Easley (1978), with a team of researchers, constructed case studies at 11 sites across the U.S. to examine how science teaching and learning occurred in K–12 American public schools. They found that although prepackaged inquiry materials such as the *Physical Science Study Committee*, and *Biological Sciences Curriculum Study* were available, teachers did not engage in these materials. Inquiry teaching was enacted to a limited extent as teachers attended to other priorities like socialization of students and fulfilling realistic and pressing demands. This and many other studies showed that ultimately, schools and teachers are never obliged to teach to the standards or prepackaged curriculum. According to Westbury (2008), the disparity between the inclusion and enactment of ‘Evolution’ in the science curriculum in the state of Kansas in 2005 is one example that shows “[S]eemingly authoritative decision making had in fact no formal authority to direct practice” (p. 46).

I am critical of the claims and recurrent portrayal of teachers in their subjugated roles rather as resisters, innovators, rebels, leaders, reformers, or changers—teacher roles that more accurately reflect the multifaceted nature of teacher agency. Teachers are active agents, whether they acted actively or passively (Datnow, Hubbard, & Mehen, 2002). In addition, agency is not something owned or endowed. Rather, teacher agency is a specialized form of power teachers have; it is delocalized, circulating, and connected to the milieu, students, and subject matter (Foucault, 1977). Teacher agency is something to

be exercised and employed by non-atomistic individuals, who act as vehicles or mechanisms of agency enactment. To have agency means being able to exert some control over embedded social relations and the ability to transform these in some degree.

In this study, I frame teacher agency as simultaneously enabled and circumscribed by the structure of curriculum change and teaching. In addition, I view agency as constitutive of abstract schema or virtual “structured properties of social systems, drawn upon and reproduced by knowledgeable agents in the course of interaction” (Giddens, 1984, p. 15)”, and physical resources in the agents’ social and cultural milieu (Sewell, 1992). These elements are activated, manipulated, transformed, and applied in different situations for various purposes.

Teacher agency and structure. In my data analysis, I draw ideas from theories of structure by Bourdieu (1977), Giddens (1971, 1979, 1981), and Sewell (1992) to analyze and discuss the source and quality of Daley’s agency at IMSA. Daley internalizes externalities and externalizes internalities (Bourdieu, P. & Passeron, J.-C., 1977) existing in this specialized STEM school. According to Giddens (1979, 1981; Shilling, 1992), ‘externalities’ refer to structural rules and resources. Structural rules are techniques or generalizable procedures applied in enacting and reproducing social practices including the knowledge of social conventions, contexts of application, and tools for actors to interact. For example, teachers apply knowledge of school routines to construct their curriculum plans. Structural resources include goods, services, and authoritative agency for control and influence.

There are primary and secondary structures (Giddens, 1984). In this study, the primary structure consists of the virtual cultural schema embodying ideologies underlying

elite education perceives as a conduit for supplying the man and brainpower for scientific advancement. The primary structure also includes actual resources such as the social and cultural capital, and finances engaged by agents to reproduce the structure. This primary structure is deep and powerful.

Chemistry, as a discipline in science, forms the secondary structure in this research context. This structure encompasses the sociohistorical context in which the concepts, theories, assumptions, procedures, reasoning, and other science knowledge are used to construct chemistry as a discipline, subject, or topics. The structure also embodies the scientific thinking applied in other scientific and non-scientific disciplines. Hence, Chemistry is a structure in which a teacher exercises agency by selecting appropriate pedagogies, experience, and thinking to engage with the resources and schema of the structure and in the process transform it through the curriculum they provide for students. This is Giddens' (1984) theory of structuration focusing on the duality of structure in recursive mutual dependence with agency. However, Sewell (1992) criticizes Giddens' conceptualization of structure as having a virtual existence and lapsing into idealism of structuralism. In Sewell's attempt to 'save' Giddens' theory of structure, he uses Bourdieu's idea to suggest that structures consist of virtual schema and actual resources, which Bourdieu (1977) refers to as "mental structures" and "world of objects" (p. 91) respectively.

According to Bourdieu (1977), there is a dialectical relationship between objective structures, and cognitive and motivating structures. The objective realities of structures are the outcome of history, prevalent views of dominant social groups, and other objective conditions. These objective conditions produce the *habitus*, which adjusts

the objective conditions; and hence, the dialectical relationship. Habitus is a durable, shared body of dispositions, classificatory categories, and generative schemes which are outcomes of collective history inscribed in objective conditions and in individuals to become second nature—durable, unconscious, intentionless intent, non-explicit reasoning, and taken-for-granted—to being (Bourdieu, 1977; Jenkins, 2002). For Bourdieu, the power of the habitus derives from the thoughtlessness of the habitus and the habituation rather than conscious teaching of rules and principles. Habitus is non-static, temporal as it represents a trajectory of probable outcomes leading to culmination of history. Human beings are social agents engaging in practices shaped by the habitus and the objective conditions of realities and reproducing habitus, hence the social and cultural reproductions of social structures to ensue its continuity and regularity. Therefore, these social agents can be said to embody habitus which is collective and mutually adjusted for and by a social class (Jenkins, 2002). *Doxa* is the tacit knowledge that social agents draws from objective realities to engage in practice but also reproduces the habitus and practice. In sum, one can almost imagine the simultaneous dialectical relationships between the objective realities of society (e.g., history, cultures, social conditions of the dominant class), habitus, practice, and doxa—each recursively producing, and reproducing the other to sustain and create patterned dispositions.

Bourdieu hints at social change when he describes habitus as embodied in the habitus (Jenkins, 2002). Giddens also talks about the dialectical relationship between agency and structure. However, structuration theory suggests relatively little about the possible direction of social change (Archer, 1988) and tends to equate agency with

consciousness, failing to consider the embodied form of human agency (Shilling, 1991). The entrapment of agents or actors within structures that reproduces remains central in their theories. This provokes an interesting question: How is agency for social change possible if structures are constantly being reproduced?

Sewell (1992) addresses the above question by suggesting five key axioms of structure transformations. The first axiom posits structures as multiple and hence agents could employ different arrays and even incompatible schema and resources in a heterogeneous habitus. This expands the versatility of the habitus and scope of agency. Second, agents decide the transposability (Bourdieu, 1977) and extendibility of the schema as they draw on their cultural schema and assess the contexts. Third, it follows from the previous point that the accumulation of resources from the enactment of the cultural schema is never predictable. Hence, the agents will always validate the schema before it is used in action; in the process, the schema is modified. Fourth, resources are *polysemy*, embodying cultural schemas such as texts and rituals. Hence, when human agents mobilize or engage resources, they have to interpret multiple meanings it bears in order to transpose or extend its use to other contexts. Last, structures intersect and overlap to mutually sustain schemas and resources that empower and at the same time constrain social action. Hence, agents can borrow schemas and resources from one structural complex and apply to the other.

In my data analysis and representation, I adapt ideas from Giddens', Bourdieu's, and Sewell's theories of structuration. I apply Giddens' idea of primary and secondary structures to organize my analysis of structures embedded in Daley's science reform work in IMSA. On this note, I want to emphasize that thinking of two structures

facilitates my analysis of the exercise of agency. In reality, these two structures intertwine and recursively influence one another as institutional ideology shape the way chemistry is taught. The inherent nature of chemistry as a scientific discipline and mode of thinking also constrains the ideologies. I also use Bourdieu's idea of habitus to describe how structures can resist change. At the end, I incorporate Sewell's ideas to examine and explain how agency is possible in the habitus of IMSA.

Overview of This Dissertation

In this chapter, I have introduced the background and context of this study, my case study participant, research questions, and theoretical framework. In Chapter 2, I will review current literature on teachers in curriculum change, identify gaps in existing literature, and hence the purpose of this study. In Chapter 3, I will describe the methodology and methods in the research design. In Chapter 4, I will represent my data and analysis of my findings. Finally, I will conclude in Chapter 5 with the implications and significance this study contributes to added understanding of teachers' agency in specialized school curriculum reform.

Background of the Author

I was trained as a chemist in my undergraduate program and worked on synthesizing anti-cancer drugs. Chemistry became a subject which I taught in three schools for approximately five years prior to my doctoral studies. My preservice teaching experience was in a Grade 7–10 public middle school offering the national curriculum (General Certificate of Education Ordinary-Level and Normal-Level) that culminates in a national examination. In this school, I taught chemistry to Grade 9 students mostly placed on the academic track leading to vocational training. My first teaching experience as a

trained teacher was in a public college preparatory school for Grade 11–12 students. This school offers the national curriculum (General Certificate of Education Advanced-Level) that culminates in a national examination. There were 16 (now 17) of such pre-college institutions. In both schools, I adhered closely to the prescribed syllabus and focused on student examination preparation using drill practices.

I was attracted to a new specialized school for gifted and academically talented mathematics and sciences, the first (there are now two) of its kind in Singapore. On listening to the founding principal, I was intrigued by his ideas of giving teachers autonomy to write the curriculum, not teach to any standardized tests, challenge students and engage them to conduct real scientific experiments, and create student-centered learning environment. His ideas were empowering and almost radical in a system traditionally set with common syllabus and reliance on the GCE results for grade promotions, tracking, college admissions, and scholarship applications. I felt I would be challenged professionally and intellectually to think as I teach. Indeed, I was encouraged and given the space and autonomy to experiment with the curriculum, apply my knowledge and skills to guide students in doing real scientific research. Although students could take the AP examination and the scores were held for student, teacher, and school accountability to the public, it was not the ultimate goal of teaching and learning.

However, my transition from a system which is highly constrained, rigid, predictable, and almost stale, to one that is novel, flexible, and ever-changing created some feelings of insecurity and frustration. I felt insecure without any guidelines or instructions on what to teach, analogous to being thrown into the open sea without a saving buoy. I was not sure if the students—identified as gifted or academically talented

in mathematics and/or science—really understood the content typically taught at higher levels or found the materials too boring. I was frustrated with some disinterested or arrogant students; some evidently did not have the right aptitude for advanced science learning. At the same time, I wondered what qualities do teachers need to have in order to teach in such schools. There were some tensions among some teachers and department subject heads during the AP examination period as they vied for extra curriculum time to conduct ‘AP’ lectures and practice sessions. Clearly, some teachers failed to see what they were doing precisely contradicted the initial goals of the school to cater to gifted students’ needs and interests and not teach to any standardized curriculum or tests.

The two school systems I experienced—one tied to the national curriculum and other divorced from it—provided two contrasting contexts for me to understand teacher agency, either too constrained or liberated, could be problematic. I became interested in understanding how teachers, particularly in specialized schools, go about their curriculum work and teach. It was with this prior experience and questions in mind that I became intrinsically interested in understanding how Daley went about his curriculum change work and teaching.

Chapter 2

Literature Review

History and Trends in Science Curriculum Reform

The 1950s was initiation of a period of prolific science curriculum reform projects such as the *Physical Science Study Committee*, *Biological Sciences Curriculum Study*, *Chemical Bond Approach Project*, and *Chemical Education Material Study*. These projects constituted the ‘alphabet soup’ period of science reform projects design and implementation. Most of these curricular efforts originate ‘top-down’ with people outside the actual school system dominating curricular decisions and material design. Teachers were members of curriculum committees, but their roles and autonomy in these projects were limited as compared to university professors, scientists, and other curriculum writers (Welch, 1979). In the early 1980s, more educators and practitioners were involved in science curriculum reform work, but university faculty, scientists, and engineers still largely dominated the remaking process. Teachers were mostly regarded as curriculum implementers of teacher-proof materials designed by a group of ‘experts’.

At the end of the 19th century, National Education Association’s (NEA) Committee of Ten endorsed a report by a team consisting mostly university science faculty who recommended teaching of science as separate disciplines—chemistry, physics, and biology. That fundamentally shaped the way science has been taught in the following decades (NEA, 1893). As mentioned in Chapter 1, in 1983, the National Commission on Excellence in Education (NCEE) published an important government report, *A Nation at Risk* in 1983, which impacted and recharted the U.S. educational landscape. The panel cautioned the extent schools in America appeared to have fallen

behind the rest of the world. Following the *America COMPETES* Act in 2007, more federal government support in educational development and progress at all academic levels in the STEM fields are advocated to address the critical shortage of citizens trained in these areas. This report subsequently became a powerful political instrument in driving STEM educational reform. In 1985, the American Association for the Advancement for Science (AAAS) sponsored a panel comprised of mainly scientists and post-secondary science educators to develop *Project 2061* for promoting national reform in science education in the United States. The subsequent publication of *Science for All Americans* outlines recommendations and goals for what this might look like. Following that publication, the National Research Council (NRC) was funded by the National Science Foundation and the U.S. Department of Education to look into creating science standards for guiding classroom instruction.

STEM Education for the Gifted and Academically Talented

In the 1950s, a group of educators became particularly concerned about the neglect of gifted and academically talented children. In 1950, the Educational Policies Commission of the National Educational Association and the American Association of School Administrators published a short treatise, *Education of the Gifted*, to address such concerns. In February 1958, over 200 educators highly interested and knowledgeable about students with above average abilities convened in Washington DC for the *National Educational Association Invitational Conference on the Academically Talented Secondary School Pupil* (Conant, 1958). The Chairman of the conference, James Conant, was earlier the President of Harvard University, U.S. High Commissioner, and U.S. ambassador to Germany. At that conference, educators discussed many issues including

program design, ways to identify and guide gifted and academically talented students, and methods to prepare teachers to teach these students. According to Conant (1959),

He [sic] is the upper 15 to 20 percent of the secondary students in the United States. (...) He is usually a rapid learner, a good organizer, and a skillful thinker; is a rule he is above average in his use of vocabulary and in his reading skills. (...) He is probably creative, curious, persevering, and capable of considerable independent study. He usually possesses more than the normal amount of stamina, is physically above average, and is fully capable of profiting by unusual academic challenges. (Conant, 1959, p. 225–227)

The definition of ‘gifted’—a subgroup in the academically talented pool—is equally (if not more) ambiguous. According to NEA, the highly gifted group constituted only two to three percent of the high school population. Witty (1959) suggested broadening the definition of giftedness in abstract intelligence and science to include consistent or remarkable performance in music, art, or writing. In the annual meeting of the *American Association of School Administrators* planned in collaboration with the *American Association for Gifted Children* held at Atlantic City the following year, Conant (1959) said the academically talented students might not demonstrate high creative powers as compared to the gifted. Strang (1959) saw creativity as sharing sensitive perception of details around, awareness and concern about unsolved problems (having the attitude of inquiry), fluency of thought, ability to concentrate, integrate knowledge, synthesize, analyze, abstract ideas, extend ideas, flexible and spontaneous, original in ideas, and so on. Conant (1959) suggested gifted students could take on courses covering breadth and depth in mathematics, science, foreign languages, social studies, and English. On the other hand, highly gifted students are often bored with the normal academic fare. They perform well on Intelligence Quotient or scholastic aptitude tests, but exhibit boredom with non-challenging tasks. He suggested creating special tasks or putting them into

Advanced Placement (AP) programs, which he saw were challenging and had low graduation rates.

Preparing teachers to teach gifted and academically talented students was another topic of concern. Several suggestions were made at the conference. For example, it was suggested that teachers of gifted children should have up-to-date knowledge of a subject and pedagogies. Teachers should ideally be academically talented as well, with emotional balance, and have enough experience to accept and work with children brighter than themselves. More collaboration between professional and academic educators was encouraged to help teachers develop deeper knowledge of the subject areas and improve pedagogies. Teachers could be involved in research and experimentation, but they should be freed from excessive administrative work or unproductive chores. To simulate children's creativity teachers should maintain an attitude of inquiry and not provide answers or authoritative pronouncements (Strang, 1959). Teachers could also encourage and reinforce creativity, for example by creating an informal atmosphere for children to express their thoughts, feelings, and ideas. Content knowledge remains important. At the conference, Strang (1959) cited Dewey's argument that one can have facts without thinking but not have thinking without facts. Strang also cited Thorndike saying, "originality and initiative grow out of knowledge, not out of ignorance" (cited in Strang, 1959, p. 28). Examinations calling for creative responses could be built in content knowledge and not have students regurgitate facts.

The AP program was conceived soon after World War II in response to school administrators and reformers call for increased academic rigor and tracking of academically-abled students (Schneider, 2009). However, the narrative on which this

program was designed was more rooted in the Cold War context. Cold War era reformers were convinced the best and brightest students could become political and scientific intellectuals and leaders. These reformers were concerned about advancing gifted students quickly and effectively through the colleges and then to graduate schools or workplaces. They assumed such students would be intrinsically driven to study the advanced material and not seek after the benefits it brings. This idea presents as an interesting contrast to how AP is sought after for its practical benefits today.

Originally offered only to selected students, AP has now expanded to become a popular program in high schools seeking this symbol of prestige and excellence, and practical benefits in college admissions, advanced college standing, and scholarship applications. But in recent years, Schneider (2009) found high status schools abandoning AP, criticizing its one-time standardized testing, the structured test-driven nature, insufficient focus on depth, and ineffectiveness in differentiating the more talented and motivated students. Nonetheless, some state colleges and scholarship providers still take AP as the acme of program rigor in their admissions and selections.

Following the STEM initiative were the proliferation of specialized schools for gifted and academically talented students highly enthusiastic in advanced science and mathematics learning. Since 1980, magnet gifted secondary schools in mathematics and science has rapidly grown in numbers (McCaleb, 1994). Beginning with only a few specialized mathematics and science schools (e.g., Bronx High School of Science established in 1938 in New York City), there are currently over 100 specialized schools in the U.S., including IMSA forming an alliance as members of National Consortium of Specialized Secondary Schools for Mathematics, Science and Technology (NCSSSMST),

In 1982, Lederman, together with Illinois Governor James Thompson, proposed to build a school for gifted mathematics and science students. In December 1983, Dr Leon Lederman, Nobel Prize Physics Laureate and Director of Fermi National Accelerator Laboratory in Illinois, invited high school teachers, college professors, scientists, and others to brainstorm a curriculum for a new kind of magnet school serving gifted students in mathematics and science (Coates, 1998). Lederman founded this school named it the Illinois Mathematics and Science Academy, where he remains as a resident scholar today.

Inquiry in Science Reform

In 1996, the National Research Council published the *National Science Education Standards* (NSES) documenting standards for students' to demonstrate ability to do and understand scientific inquiry, and teachers to teach scientific inquiry. However, such authoritative documents do not seem to direct practice in authentic inquiry teaching. Windschitl (2003) found in his study on six preservice teachers that those with laboratory research experience were more prone to conduct inquiry in their classrooms and if they did, it resembled the way they conducted their laboratory investigations as students. This finding was coherent with Pomeroy's (1993) study which found that teachers often conflate scientific inquiry with scientific method—a universal set of prescriptive procedures which involves hypothesis making, designing steps to test the hypothesis, making explanations based on gathered evidence, and finally evaluating the finding. Further, teachers might have different ideas about inquiry from those of researchers (Abd-El-Khalick & BouJaoude, 1997; Lederman, 1992).

Contrary to procedural, predictable, fixed, and clear conceptions of inquiry teaching, Schwab (1962) said, “teaching of science as enquiry [inquiry] is ambiguous” (p.

65) as the process of teaching and learning is itself inquiry and science is itself inquiry. Students can identify discrete components, find ways to connect them and construct whole meaning. Teachers can clarify and inculcate a body of knowledge dependent on methods used to generate wholistic knowledge. There is no single method to teaching inquiry (NRC, 2000) as a repertoire of approaches to inquiry teaching can be used depending on the goals and purposes of the teacher, the content, students, and available resources.

Teachers as Curriculum Makers

Teachers' roles, knowledge, and experiences in curriculum making have been reported in many studies (Bullough, Knowles, & Crow, 1991; Connelly & Clandinin, 1988; Goodlad, Klein, & Associates, 1970; McDonald, 1992; Olson, 1982; Spears, 1951). For example, Clandinin (1986) discussed how two elementary teachers' images of 'classroom as home' or 'language as the key' are constitutive of their personal practical knowledge in curriculum making. Bullough et al. (1991) examined the process six preservice teachers emerged to become teachers in their own classrooms. One teacher was a graduate student in biology and worked as a laboratory technician before teaching. He experienced emotional turmoil while struggling to teach inquiry and manage disruptive students' behavior at the same time. He felt the transition from an expert with autonomy in the laboratory to 'immobilization'. Murphy, Evertson, and Radnofsky (1991) found that teachers' self-esteem and positive perception of school climate—having school support of professional development, autonomy, and students' outcomes—are critical factors in the product of reform. Organizational and perception

variables influence the way teachers assess if it would be worthwhile to play a role in a reform process (Weiss, Cambone, & Wyeth, 1991).

Problems and Limitations on Research in Science Curriculum Reform

Despite extensive research on teachers' curriculum making in science reform, I find three major limitations that hinder deeper and more critical understanding of the nature of teacher agency in curriculum making. First, most studies frame teachers' curriculum work as curriculum *implementation* of externally imposed science reform curriculum rather than a form of *enactment*. Second, teacher resistance to implementing curriculum changes is perceived as a failure of curriculum reform efforts rather than a form of teacher agency. Third, failures of reform are attributed to technical and isolated treatment of factors such as lack of resources, time, and support neglecting more complex forms of interplay with classroom dynamics. I will now discuss each of these and propose alternative views.

First, research on teachers' curriculum work often focuses on the implementation of prescribed curriculum standards or predesigned curriculum packages premised on the assumption that teaching could be manipulated by "training the trainer" (Haney, Czerniak and Lumpe, 1996). Policy makers and external curriculum writers assumed they knew what was best for students; that teachers would interpret and know how to deliver the prescribed content as intended by them. This could be seen as perpetuating the problem of proletarianizing (Apple, 1986; Giroux, 1988) teachers' work reducing them to technicians within the bureaucracy of schools managing and implementing rather than critiquing, leading, initiating, or claiming authority in writing or developing the curriculum materials in response to students' needs. As such, the national and state

standards in science inquiry and science curriculum reform materials were often ineffectively used in teaching (Anderson et al., 1994). In a study on teachers' implementation of the Schools Council Integrated Science Project, Olson (1982) found inquiry teaching of 'doctrinated' radical project failed because teachers perceived inquiry teaching to be difficult, felt uncomfortable with limited control over the outcomes and process, and had little experience with the approach. In Davies' (2003) study of a middle school that field-tested new curriculum material, the teachers were explicitly told not to modify or adjust the curriculum activities but implement as written. She found this approach had limited the incorporation of teachers' prior knowledge and adversely affected teachers' acquisition of new knowledge and skills. In such studies, the focus was on the extent of fidelity of implementation which necessarily framed teachers as assembly-line workers receiving instructions and dispensing information as instructed.

Aoki (2005) precisely argued against such instrumental view of teachers. He said,

What is objectionable is the fact that viewing the teacher instrumentally effectively strips him/her of the humanities of his/her being, reducing him/her to being-as-thing, a technical being devoid of his/her own subjectivity. Reduction to activities within the instrumental process renders irrelevant the subjectivity of the teacher. I find such reductive rendering oppressive. (Aoki, 2005, p. 115)

The problem with the concept of curriculum *implementation* is that this process simply devalues teachers' experience and knowledge. Teachers work in contested and conflicting contexts; hence to examine "any notion of teacher agency guided by an overarching, unitary agenda is unworkable and inappropriate" (Pignatelli, 1993, p. 428).

Giroux (1988) suggested rethinking and restructuring the nature of teachers' work by viewing teachers as *transformative intellectuals*. As such, teachers' work is viewed as intellectual rather than technical or instrumental labor. Teachers participate in

(re)producing and legitimizing the social, political and economic interests they affirm and adopt through their pedagogical choices. To examine this, ideological and practical conditions teachers need to function as intellectuals must be identified.

In viewing teachers as transformative agents, their thinking in all human activities must be examined critically. Teachers' thinking, as a form of contextualized, accumulative, and unique professional thought, has dialectical relationship with teachers' knowledge. As teachers teach, they think, reflect, and make decisions by drawing on different kinds of knowledge including content knowledge, general pedagogical knowledge, curriculum knowledge, subject matter knowledge, pedagogical content knowledge, propositional knowledge, case knowledge, strategic knowledge, and knowledge of learners, educational contexts, and education goals (Shulman, 1986, 1987). Teachers also have personal practical knowledge combining personal meanings and practical experiences (Connelly & Clandinin, 1988; Johnson, 1989; van Driel, Beijaard, & Verloop, 2002) and using their knowledge in adaptive ways to manage dilemmas (Lampert, 1985) in changing, interrelated, competing, contradicting, conflicting, and contextually dependent situations and decisions to pursue desired goals. This personal practical knowledge is embodied in nature (Johnson, 1989) as the locus of complex interactions with the subject matter, students, other stakeholders, and milieu. In the process, this embodied knowledge is changed as well. When teachers engage in curriculum making and teaching, they often base it upon abstract theories (which can be regarded as developed in isolation from practice) and practical theories as directives to apply in their classrooms. They often set out to accomplish this by manipulating the environment and controlling learning experiences and behaviors of learners in varied

degrees, rather than allowing them to learn what they do not know. Hence, this practical knowledge can be described as personalized, contextualized, speculative, and interactive (Clark & Lampert, 1986) and possibly constitutive of the different kinds of knowledge that Shulman (1986, 1987) identified. In particular, pedagogical content knowledge gain through integrative experiences can be central to the practical knowledge of experienced teachers (van Driel et al., 2002). Hence, teachers' knowledge is rich; neglecting teachers' knowledge greatly undermines their position as educators who, in reality, hold the final say over what is taught and how science is taught (Goodlad, Klein, & Associates, 1970).

In curriculum reform initiated by teachers, they are positioned as active rather than proactive agents of change. Parallel to this idea is the view of curriculum *implementation* as curriculum *enactment*. Curriculum enactment is an alternative approach to understanding how teachers engage in curriculum work with situational praxis (Aoki, 2005), valuing teachers' knowledge, identities, and subjectivities in the transformative process by challenging hidden assumptions and ideologies with actions for change. To view curriculum as *enacted* is to examine how the curriculum is shaped through evolving personalized constructs—curriculum knowledge, the change process, and teacher roles—of teachers in the process of interacting with students (Synder, Bolin, & Zumwalt, 1992). This knowledge is not a product or event but an ongoing process constructed as teachers draw on external resources and their own to create context-specific curricular knowledge. The meanings of effective and successful teaching and learning as enacted in contextually adaptive curriculum is jointly created, rather than received, by the teachers and students. Further, in order for educational reform to be effective, the strategies have to take root at local levels such as school districts, schools,

or classrooms (Bybee, 1993; Clark & Astuto, 1994; Cuban, 1990; DeBoer, 1991; Fullan & Miles, 1992; McLaughlin, 1990).

The context of most research is public schools subjected to accountability measures such as high-stakes testing under the *No Child Left Behind Act* in 2001. Teachers, although not strictly bounded by the mandates, often teach to the test (Cuban, 1990; Linn, 2000). In accredited college preparatory classes such as AP, the number of teaching and laboratory hours, and curriculum content are prescribed. Teachers are constrained in making curriculum changes in real classroom contexts. However, the landscape of U.S. education is diverse and some schools such as IMSA are not held accountable through statewide high-stakes testing. In addition, they are relatively well-funded and have highly qualified teachers and bright students motivated in learning. Such schools are interesting contexts to examine how teachers *enact* curriculum changes in reform efforts they initiated.

The second limitation of research about teachers is that they are often criticized for resisting curriculum reform changes, preferring to teach in previous ways using the existing curriculum. However, teacher resistance should not be conflated with rebellious “acts of behavior that are either one-sidedly self-indulgent or are linked to the dynamics of domination” (Giroux, 1983, p.106) because not all oppositional acts are reactions to domination or authority. Rather, teacher resistance could be reframed as a political form of ‘good sense’ (Apple, 1986; Gitlin & Margonis, 1995) informing teacher praxis and helping us to better understand why certain curricular decisions are made. In their study of a site-based curriculum reform, Gitlin and Margonis (1995) inquired into elementary teachers’ narratives and found them resisting the reform and external researchers. The

teachers' resistance was reinterpreted as having good sense as they had genuine, rational, and insightful concerns and considerations pertaining to the school culture constraining their reform. Some teachers overtly showed their resistance by voicing their suspicion of the researchers as evaluators, while others quietly did their work at the meetings.

Teacher resistance can be political and public acts aimed at transforming unequal or unjust distribution of power and responsibility (Stone, 1988). This is a more proactive form of teacher resistance pointing towards transformative acts and social change. Teachers use it to keep and fulfill the core elements of their curricular demands, and at the same time maintain smooth classroom functioning and meet new expectations (Olson, 1988). Alternatively, the resistance can also be private and quietly directed inwards on assumptions, knowledge, and experience to maintain opportunities for initiating, creating, and evaluating curriculum (Paris, 1993). This is a more defensive form of teacher resistance to deflect threats to their teacher agency. These two views expand our knowledge of teacher agency constructed through the lens of teachers.

Third, failures of reform are attributed to technical and isolated treatment of reasons and factors such as availability of physical resources, curriculum materials, supportive administration, professional time, development opportunities, and parents' expectations required for reform to succeed (Bybee, 1993). While these real, individual, institutional, and situational factors are important considerations, there are less apparent factors and forces shaping the processes and outcomes of curriculum making. Apple (1986, 1996, 2004), Cuban (1995), and others have argued how the 'hidden variable' in the organizational structure direct the taught curriculum, official curriculum, tested curriculum, and learned curriculum within the spaces of the classroom. This 'hidden

variable' comprised of organizational influences and the culture of the school district deeply ingrained in the norms and expectations of the different stakeholders of education—including the community to which the school belongs, and the existing school organization such as differentiated curricula, assessments, and age group separation. A different kind of complex problem in curriculum making that is more insidious and deeply rooted in ideology is implied. While most studies identify and discuss factors constraining teachers' curriculum work in reform imposed on teachers in public school contexts, below the facade are possibly rhizomatic (Lather, 1993) interplay of individual, sociocultural, sociopolitical, socioeconomic, and historical factors and forces penetrating fine veins of the school administration, curriculum, teaching, and learning. Hence, there is a compelling need for critical lens and alternative orientation towards research on teachers curriculum making.

Currently, there is a lack of empirical studies with critical lens examining how teachers are constrained in their curriculum work and teaching. Some studies (Bullough et al., 1991; Clandinin, 1986) tried to value subjects' voice by creating narratives or thick descriptions of the site and events. However, many narratives lacked critical interrogation of traditional power structures, power relations, and discourse practices embedded within a specific context which could distort teachers' agency. According to Sarason (1996), not to deal with the issues of power relationships is to grossly underestimate the work of curriculum reform. The nature of one's status in a power relation can determine the activity one could engaged in, the amount of voice one is given in decision making, and power one has within the educational and professional contexts (Davis, 1999, 2001). Schools are political instruments because the structure, decision making process,

formation of social relationships are shaped by unequally distributed powers. There are always tensions underlying curriculum work because it is positioned at the intersection of complementing, contradicting, and conflicting personal, historical, social, institutional, and political ideologies. Science inquiry curriculum reform—as described earlier in the brief historical account of its emergence, evolution, and recurrence—embodies such ideologies connected to imbalanced power relations between individuals and groups—scientists, university science faculties, and politicians—invested with personal, collective, and institutional interests and power relational to class; also gender and race. These issues will be taken-for-granted if left unexamined. Hence, they should be critically addressed for any transformative changes to occur (Davis, 2003).

Critical examination of teacher agency as embedded within structures of ideologies would necessarily address the issue of tension teachers face in curriculum making. Tension is often associated with negative meanings—hindering, obstructing, and frustrating change. However, it can also become a force provoking, driving, and catalyzing actions for change or searching for means to resolve or overcome constraints. This may result in greater dynamic interactions between people, wiser decisions made, stronger professional commitment, positive feelings, and other positive outcomes.

In this section, I have discussed three limitations of current literature on teachers' curriculum making in science reform. I have also identified spaces and gaps to extend the boundaries to include more critical conceptualizations of such studies. This approach re-frames teachers as active participants and co-constructing agents of curriculum making. For the rest of this chapter, I will elaborate on critical educational research, teacher resistance, and teacher agency.

Towards Critical Study in Curriculum Reform Making

Critical educational research is not research *on* or *about*, but research *in* or *for* education and the problems and issues must be understood as situated in the present and in history. Critical research seeks to uncover dominant social constructions and transform or liberate people from dominant oppressive forces. Research conducted in these critical perspectives offer modes of teacher intervention through the curriculum and their practices to transform educational and social processes. The research process is one of conscientization (Freire, 1970) or enlightenment on students' real needs and desires, revelation of false ideas, distorted ideologies, and mechanisms in oppression, and identification of inherently contradicting social conditions creating specific needs and causing dissatisfaction. The consequences of self-organized enlightenment, as such, include 'dealienation' from certain divisions of social groups and class, empowerment, and detachment from authoritarianism.

Critical educational research is practical in informing and guiding actions to overcome problems and eliminate frustrations, helping teachers develop praxis through curriculum making. Some issues addressed in critical studies on curriculum reform pertain to: (a) the research and researcher—what is the politics of the researcher; how are the subjects constructed in this study; who is the research for, and; (b) the research topic—what counts as knowledge; who decides the curriculum; whose interests are served; how is individual agency exercised, legitimated, transformed, or limited; what are the inherent and apparent factors constraining or frustrating change and how; what information and knowledge do we need in order to address related problems and issues;

what counts as good teaching or learning. Most importantly, who gets to answer all these questions (Apple, 1996).

The common goal of critical educational research is to emancipate teachers and students from restraining factors which are products of social processes acting to reproduce themselves through schooling and education in subtle and insidious ways. It also helps to demystify ideologies distorting dominant and social relationships. The goal is typically concerned with raising consciousness levels of teachers, parents, students, school administrators, legislators, curriculum planners, and the school community on such issues. It also seeks to expose and scrutinize the underlying covert assumptions and tacit values of schools and society (Eisner, 1992).

Educational issues are framed as social issues in critical research. Curriculum making, teaching, and schooling are processes of social and human construction of meaning embedded in historical, sociocultural, sociopolitical, and political-economic structures and power (Apple, 1986). These ongoing processes involve a complex interplay of ideological and material structures of control. According to Apple (1996) and Giroux (1983), the reality we live in is increasingly disparate—economically and politically—as school policies, school curricula, teaching practices, and evaluative practices conform to the needs of powerful and dominant groups. Teachers make and act on decisions encompassing attitudes, beliefs, and values that institutions want to sustain (Carr & Kemmis, 1996).

Many researchers including Grundy (1987), Apple (2004), Carr and Kemmis (1996), Connelly and Clandinin (1998), and Tobin, Elmesky, and Seiler (2005) based their work on the critical view that teachers are oppressed in their professional sphere.

The process in which teachers are cut off from their own thinking and rely more on ‘expert’ materials is described as *skill diversification* and *intellectual deskilling*. *Intensification* is also “one of the most tangible ways in which the work privileges of educational workers are eroded” (Apple, 2004, p. 41). This process destroys the sociability of people causing self-direction to be lost and depriving them of leisure as they continually race to keep up with their profession. Apple (2004) cautioned teachers not to misrecognize this “absent presence” (p. 45)—entails increased control, technicalization, intensification, and proletarianization of their work—as a symbol of professionalism, but to challenge it and regain control. The word ‘hidden’ suggests some form of concealment from the public’s eye. Therefore, “hidden curriculum is often believed to serve the interests of the power elite, which the school itself is covertly thought to serve” (Eisner, 1992, p. 314). To address issues and problems on curriculum reform with a critical lens, attention must be given to the nature of teachers’ agency within the school structure, and its hidden curriculum consisting of the language, knowledge, materials, programs, school structures, and other resources.

Under this critical view, teachers take sole responsibility in initiating curriculum change (Grundy, 1987). Teachers become empowered professionals and subject experts having the responsibility in *social justice* to act truly, justly, and wisely in the interests of students (Carr & Kemmis, 1986). For example, teachers should be critical of what they do that enables or limits students’ access to opportunities in the social world. When teachers are emancipated from these factors constraining or frustrating social and educational changes, they can participate in more authentic curriculum development and reform work for democratic education. Teachers will transform out of current practices

such as abandoning consumerist attitudes of teacher-proof curriculum materials to become more critical of what they read, see, or hear, and probe beyond surface appearances to challenge common wisdom and work towards democratic education. In the process, the quality of service to people will improve.

However, teachers' actions are often the product of custom, habits, coercion and ideology constraining teachers in ways that they do not recognize. To emancipate teachers from their dependence on habits, traditions, and coercions, a few things must happen. First, power—or transformative capacity intrinsically related to agency (Giddens, 1984)—must be shared among school administrators, curriculum planners, scientists, politicians, researchers and teachers respected as professional educators and experts. Second, teachers must be provided with skills, resources, and opportunities to reflect, critically examine, expose, and eliminate inadequacies in their educational practices. Teachers have emancipatory roles in curriculum development, reform, and transformative education. The goal could be to achieve greater social justice through teacher empowerment as they develop competency to take charge of their own growth of skills and knowledge to act on situations for improvement (Short, 1994). It could also aim at achieving democratic education, greater self-awareness of possible null and hidden curriculum, and/or engagement in culturally and socially adaptive practices to tap on and extend students' symbolic, social, and cultural capitals.

In the process of becoming more critical about their work, teachers could become capable of distinguishing ideologically distorted interpretations and self-understandings from those that are not. They could devise ways to overcome distortions through reflexivity—consciousness of self and other in the process of self-scrutiny

(Chiseri-Strater, 1996)—to gain deeper insights in the social workings of the world and how this knowledge is produced. Being reflexive entails having ongoing dialogue about previous experience while living in the present moment (Hertz, 1997), being critically conscious of identities (race, gender, class, sexuality, ethnicity, and nationality), positionalities (such as personal bias and theoretical lens), and interests that affects one's lens, orientations, viewpoints, and assumptions. The notion of reflexivity, when applied to thinking, doing, and representing critical educational research examining teachers' agency in structures of curriculum making, leads to development of *praxis*. Phronesis or practical wisdom is needed for praxis to do an activity right and well with others. This constitutes practical-rationality (Schwandt, 2007), different from *techne* when teachers base their work on pre-determined objectives and judge outcomes of teaching in terms of effectiveness and efficiencies. On the other hand, teachers who based their work on practical-knowledge constitutive interests regard their ideas as principles and rely on their practical judgment to make decisions. This practical knowledge encompasses their theories, philosophies, beliefs, principles, and values about teaching and learning. Practical knowledge embodies purposes in a deliberative and reflective way. It is the way one thinks about oneself in teaching situations and relates to reconstruction of meaning contained in actions and narratives of experience. It is also what we respond with when someone asks what we believe in not as espoused theory, but contextualized beliefs and values in experience. Teachers put their ideas into actions, reflect on their own practices, question why students need to learn material, decide how they want their students to learn, how to assess students' learning, and account to school administrators, parents, the school community, and legislators. This relational thinking of themselves, their students,

school, and larger context is a reflexive act that involves acting recursively on one's own personal beliefs, values, philosophies, ideologies about teaching and learning; students' aptitude, attitudes, abilities, and characteristics; institutional beliefs, values, and constraints; and other external macro expectations and goals. The thinking and actions may converge or diverge, but decisions are weighed and outcomes are used for reflection and to inform the next decision and action.

What does it mean to conduct critical research on curriculum reform with praxis? There are two parts to this question: (a) critical educational research as praxis, and (b) curriculum making as praxis. I will now discuss these two sets of ideas and particularly the second idea at greater length to enter the discourse of teacher agency and resistance literature.

Critical Educational Research as Praxis

First, to conduct critical educational research with praxis is to “involve the researched in a democratized process inquiry of inquiry characterized by negotiation, reciprocity, [and] empowerment” (Lather, 1986a, p. 257). Reciprocity is achieved when there is mutual negotiation of meaning of power (Lather, 1986a) between the researcher and researched, theory and data, and agency and structure. The lack of reciprocity in negotiation of meanings could lead to false consciousness (Lather, 1986a) as denial of how our commonsense ways of viewing the world is permeated with meanings sustaining disempowerment (Gramsci, 1971). In empowering research work, teachers can participate as researchers or coresearchers in planning, collection, analysis, interpretation, and dissemination of research findings. Researchers could collaborate with teachers or help them understand and change their situations. Both groups are valued in the process

of inquiry as they work together to formulate problems and questions, interpret, and discuss findings. The research process becomes empowering when it invokes democratization of knowledge and power, arouses researchers' and participants' positive attitudes, and greater self-determination to improve their own situations. An important approach to critical research is to ground it in history. In Apple's (1986) book, *Teachers and Texts*, he illustrated how the politics of texts is related to relations of class, gender, and teaching and grounded in history. This thinking enables one to understand how current situations and attempts to restructure the curriculum are based on (e.g., economic, gender, and political dynamics) and established from the past.

Curriculum Making as Praxis

Praxis becomes possible when the process of engaging in curriculum making becomes a lived and struggled experience. Praxis is really more than just meaning making; it is the act of performing informed action (Carr & Kemmis, 1986) based on a knowledge base which is in turn changed by the action that re-informs it. Hence, praxis is a dialectical process, method, and way of thinking that surfaces contradictions, questions, and troubles, and blurs binaries such as means-ends, process-product, and subject-object. In the dialectical view, the constitutive elements are not in opposition but mutually constitutive. Educational experiences are, therefore, dialectical because

[I]t is a process that takes on the world without appropriating that world, that projects the self into the world without dismembering that self, a process of synthesis and totalization in which all the participant in the dialectic simultaneously maintain their identities and surpass themselves. (Grumet, 1992, p. 32).

To view curriculum making as praxis is to view teachers' curriculum work as a transformative act of consciousness raising as they perceive and act in their locally

(schools and classrooms) situated and externally (district meetings, conferences, and outside-school professional development courses) located social and cultural contexts. Their consciousness may be guided by some personally constructed interests which determine how they form their professional knowledge, but these interests may meet with contradicting or conflicting interests of the school, other stakeholders, the larger school community, and society.

Teachers have to work with diverse interests and negotiate the dominance of varied and even conflicting interests as they make decisions and act upon them. They are not merely transmitters or executors of curriculum. Their roles in curriculum development and teaching evolve as they become reflexive in praxis. When teachers engage in praxis, they practice self-reflexive, dynamic, creative meta-practice of individuals and communities which in turn is its own meta-praxis (Lemke, 1995). While engaging in critical praxis, teachers have to examine themselves, their own actions, beliefs, and values to see how they connect to larger patterns and processes of the system of which we are a part, to understand how they are part of both problems and solutions (Lemke, 1995) as they participate in the process of social control.

Most school curricular decisions are established through consensus rather than conflict (Apple, 2004) or diversity. Conflicts and diversity are more reflective of the complex nexus and contradictions of social life. In *Curriculum: Products or Praxis*, Grundy (1987) described the active co-construction of learning experiences with students as having a 'transactional' relationship between teaching and learning, that is the negotiation of power relationships and knowledge between teachers and students. The

intrinsic meaningfulness of the experience curriculum making produces could arise from dialogical negotiations between the teacher and students as Freire (1970, p. 65) described:

Thus, the dialogical character of education as the practice of freedom does not begin when the teacher-student meets the student-teachers in a pedagogical situation, but when the former first asks himself what the dialogue with the latter will be about... for the anti-dialogical banking educator, the question of content simply concerns the programme about which he will discourse to his students; and he answers his own question, by organizing his own programme. For the dialogical, problem-posing teacher-student, the programme content of education is neither a gift nor an imposition... but rather the organized, systematized, and developed 'representation' to individuals of the things about which they want to know more.

Thus, meaningful experiences are not accomplished from one-way communication or determined from the products or ends. Rather, these meanings are negotiated, valuing the voices and experiences of teachers and students in the pedagogic act. This view, however, does not suffice as an emancipatory curriculum unless it also takes on the critical view of the pedagogical act and processes which problematize the experiences of teachers and students as they engage in the dialogic process and negotiations of their agencies within school structures.

Teacher Agency and Structure

Theories of human or subject agency center the construction, interpretations, and applications of meanings by social agents and are rooted in symbolic interactionism described by Herbert Mead (1934), George Blumer (1969), and Erving Goffman (1959, 1975). On the other hand, theories of structuralism or functionalism by Anthony Giddens (1979, 1981) and Pierre Bourdieu (1977) prioritize objects and structures over human actions. However, the 'dichotomies' between these two sets of views do not exist. Although it may be more accurate or fair to say each set of theories places its stake, value, or emphasis on different centers that explain, describe, elaborate, extend, or

account for the social phenomenon observed, none of these theories engage in conversations with these ‘centers’ in pretense of the absence of the other. As mentioned in Chapter 1, I engage the dialectic stance of agency and structure purported mostly by Sewell (1992) to examine teachers’ agency in dialectic with structure. A dialectic view means mutual engagement but it does not imply equally balanced views. I want to emphasize that in this case study of a science teacher, I have chosen to value or center his agency as embedded within the specialized school structure. This structure is not a backdrop, but the context in interaction with teacher agency.

Qualities of agency. Agency involves negotiating roles, identities, knowledge, and power relations between participants in the field and between individuals with the structures of their experience and work. According to Giddens (1984), “Agency refers not to the intentions people have in doing things but to their capability of doing those things in the first place” (p. 9). Agency entails the ability to “act otherwise” (p. 14), not as a perpetuator of events, but to bring about a different state of affairs or course of events. Teacher agency, as a malleable or dynamic form of professional power (the intent, will, capacity to achieve desired outcomes (Giddens, 1984)) can be acquired, self and co-constructed, or endowed in multiple ways. For example, teachers become more conscious of the knowledge they have through better self-understanding of their own constructed identities embodying assumptions, beliefs, prior experiences, values, morals, ethics, roles, history, social and cultural backgrounds.

Much progressive work has been written on the connections between schooling and the labor market by scholars such as Apple (1986, 1995, 1996, 2004), Giroux (1988, 2001), Bowles and Gintis (2002), and Willis (1981) adapting Marxist ideas of class. For

example, formal schooling is often said to help reproduce the social division of labor in the economy. Their ideas fundamentally problematize schooling as an issue of imbalanced class and class relations. In this sense, schooling reproduces class systems and are products of it. Teacher agency can be regarded as trajectories of historical, social, cultural, and economic backgrounds of their families and communities, political ideologies, and larger social systems delicately, intimately, and symbolically linked to their class. These factors and forces affects teachers' effectiveness in engaging specific pedagogies, role modeling to specific groups of students, and transmitting socioculturally-sensitive values, stances, outlooks, and preferences.

Dominant cultures must be critically understood before they can be transformed (Gramsci, 1999). Hence, being critical is an important quality of teacher agency. Teachers with critical views value knowledge and understanding from diverse intellectual, cultural, and scientific traditions of people from different racial, ethnicity, and gender (Connelly & Clandinin, 1988). They view themselves as decision makers of policies, organizations, and procedures governing their profession by participating in deliberation, and collaboration to make informed personal and collective decisions and work for the good of students and the larger community. Their attitudes and practices also become more firmly grounded in educational theory. Teachers who are critical researchers, research participants or subjects of critical research can transform to undertake identities as they emerge from politics of struggle, oppression, or exploitation in order to have a standpoint on the critique of dominant structures and forces (Talbert, 2000) and resist the reproduction of dominant social practices and cultures. This identity

embodies the positionalities, subjectivities, experiences, and capitals one has as she or he speaks or acts within the situated context.

The task of critical teachers is to understand how particular students give meaning to the world (Giroux, 1988). To do this, teachers must have voice and learn how to move outside their own frames of reference to develop a more rational view of the world needed for counter-hegemonic struggles. Teachers are hence, intellectuals helping students to appropriate their own histories, examine critically their own relations with students forming oppressed groups, hegemonic practices, and ideologies sedimented in the social relationships in and outside classrooms, and manifested in curriculum materials, pedagogies, curriculum, classroom practices, and behaviors and attitudes (Gramsci, 1999).

Teachers' role in curriculum reform should not be reduced to 'screens' in implementation (Carr & Kemmis, 1986). Rather, they perceive and enact different roles such as referee, observer, controller, professionals, and entertainers (Olsen, 1981; Sloan, 2006). In addition, teacher roles shift from being navigator, to prime mover, and even director as they manage their dilemmas by trying to regain control in the reformed curriculum which calls for more student discussions.

Further, teachers should not be curriculum implementers but deliberators (Sloan, 2006). When there is 'null' and/or hidden curriculum, certain things are deliberately left out or contain implicit messages reproducing a hierarchy of social structures that benefit some students at the expense of others. What appear to be 'neutral' curriculum materials may contain hidden messages and enhance the cultural, social, and gender divide. Hence, these are critical issues teachers should pay attention to developing and reforming the

curriculum (Connelly & Clandinin, 1988). It will benefit them professionally as they think about and address these issues in their curriculum and practice and it reduces the possibility of teachers and their work being overruled by others. They also learn to make reasoned curricular decisions and defend their professional judgments and decisions based on the authority of knowledge and not the person in political power or authority. In protecting their own space to exert their professional autonomy, teachers would act against imposed external factors or views.

Agency as circumscribed in structure. Agency is circumscribed by the structure affording it such that even the most autonomous agent is some degree dependent on others and the most dependent social agent will always retain some autonomy. Agency as circumscribed does not imply dissolution of acts or replacement of power to act otherwise with 'reaction' (Giddens, 1984). As teachers engage in their students' resources, their own resources, and other resources within and beyond the structure of the community, home, school, and classroom, they are said to be exercising their agency to make informed decisions.

Structure is constitutive of cultural schemas and sets of resources participants can access and mobilize so that that they can enact the schema. But structures empower agents differently because they have access to different kinds and amounts of resources depending on their age, social class, sexuality, and wealth, and hence different possibilities for transformative action. Teachers are empowered differently in these structures because they have access to different kinds and amounts of resources depending on their age, class, race, sexuality, and wealth, resulting in a different extent of transformative action. Curriculum and teaching take place in structures constitutive of

human and non-human resources such as rules, principles, and schemas that result in patterning of social life over sustained periods. According to Tobin et al., (2005), sociocultural, sociopolitical, and economic forces shape schools, curriculum, teaching, and learning in ways leading to social injustice and inequalities, and oppression of social relations. Conversely, schools also play powerful roles in perpetuating these systems such that socioeconomic positions of certain social groups are reinforced.

The agency | structure dialectic. Teachers could become empowered to do curriculum development and reform work if they work reflexively around the agency | structure dialectic (Tobin et al., 2005). Teachers exercise their agency to access and mobilize resources and strategies in and outside the institutional structures so that they can enact these schema to change the curriculum and teach. Their work is in turn dependent on resonant conditions and factors within the structures to participate, act, decide, initiate, and perform their role. In the sociocultural perspective, teachers' thinking, beliefs, and actions are products of cultural, historical, and social structures reflected in mediation tools such as arts literature, media, and technology systems (Wertsch, Tulviste, & Hagstrom, 1993) or policy mandates, curriculum standards and guidelines, and school norms. In particular, an alternative (critical) notion of culture in Freire's (1985) terms is one that does not merely represent that of the ruling or dominant group and existing configurations of power. I will quote Giroux at length on his summary of Freire's idea of culture which I use in my data analysis:

For Freire, culture is the representation of lived experienced, material artifacts, and practices forged within the unequal and dialectical relations that different groups establish in a given society at a particular historical point. Culture is a form of production whose processes are intimately connected with the structuring of different social formations, particularly those that are gender, age, racial, and class related. It is also a form of production that helps human agents, through their

use of language and other material resources, to transform society. In this case, culture is closely related to the dynamics of power and produces asymmetries in the ability of individuals and groups to define and achieve their goals. Further, culture is also an arena of struggle and contradiction, and there is no one culture in the homogenous sense. On the contrary, there are dominant and subordinate cultures that express different interests and operate from different and unequal terrains of power. (Giroux, 1988, p. 116–117)

Freire's (1985) conception of cultural power provided a pedagogical twist to the politics of education. Teachers learn to work *on* and work *with* their own and students' experiences and capital to bring it to the contexts of teaching and learning. They critically examine these experiences for strengths and weaknesses, appropriating moments of emancipation, and exercising leadership. Hence, critical pedagogy, which I argue is constitutive of teacher agency, is established through exercising this cultural power.

In the dialectic view, agency is always mediated by interactions between individuals and others' attributes, qualities, and dispositions with the resources and tools of structures of schooling. Agency is thus often conceived as socially negotiated and encultured (Cobb, 1989) rather than internalized or consumed. It is important to note that this mediation need not be perceived as restraining, limiting, or negative. Hence, it may be beneficial to move away from the 'all-good' or 'all-bad' discourse on accountability and accountability-explicit curriculum policy to suggest possibilities of using them as guides and resources to improve overall quality and equitability of classroom practices (Sloan, 2006).

The dialectic relationship between agency and structure can be a reflexive process as teachers negotiate the process to examine what they can do, how they can engage the resources, what values are important, and how to overcome issues, problems, or obstacles as they develop better and more effective reflexivity in curriculum making.

This is coherent with Freire's (1985) dialectic views of theory-practice relationship. Contrary to Marxists intellectuals' view on theories *for* practice, Freire's (1985) and Gramsci's (1999) concept of intellectuals is organic—oppressed individuals emerge from the social contexts, make meanings and construct their own worldviews, engage in transformative actions and struggles. These organic intellectuals fuse theories from the masses and oppressed to remake conditions for emancipatory actions. For example, in Tobin et al.'s (2005) work with urban school science teachers, they infused their theories of science with students' prior experiences, language, culture, and values to develop socially and culturally-adaptive science curriculum. This transformative curriculum and teaching can promote development of positive emotional energy in students, energizing them to learn (Tobin et al., 2005). Teachers could also enact science with fluency as they personalize and internalize their own understanding and praxes. Teachers and students will develop solidarity (Tobin et al., 2005; Welch, 1985) in the process of making collective agreement and sharing responsibilities with their colleagues and peers.

Teacher Resistance as Teacher Agency

Bleak imageries of teachers' work are portrayed as teachers are often described as severely constrained in their curriculum decision-making (Bullough, Gitlin, & Goldstein, 1984). For example, teachers are said to have minimal say over the outcomes of education as they could only decide the means to achieving others' ends. Hegemonic cultures (Apple, 1996; Bocoock, 1986; Gramsci, 1990; 1999) appear to lurk in every corner and aspect of teachers' work as dominant groups in society subordinate teachers and their work.

Although these problems are real and serious, teachers are capable of resisting constraints imposed on their professional agency (Bullough et al., 1984; Gitlin & Margonis, 1995). Teacher resistance can thus be viewed as a form of teacher agency exercised and a fundamental component of teachers' action. Teachers do not always passively accept the constraints imposed and act as "dispenser-clerk of curricula" (Bullough et al., 1984, p. 357) or respond to mandates in "predictable, mechanistic, or unidimensional ways" (Sloan, 2006).

Freire's (1985) notion of 'conscientization' is key to understanding the idea of transformative change process for human agents. 'Conscientization' is not merely gaining consciousness through reflection of reality but to have a view of the world as always dynamically in the making or unsettled, and constantly seeking ways to clarify what is internally hidden as we act in this world. Dominant cultures never encompass the whole field but struggle with new and existing cultures (McGuigan, 1992). Teachers also resist domestication by cutting corners to eliminate what seems to be inconsequential to the task. Apple (1986) commented it is not unusual for new or reformed curriculum to be taught in the same manner as the old curriculum as teachers alter it to fit into the existing regularities of the institutions and prior practices that had proven successful in teaching. They may also modify pre-specified objectives they think are not relevant or as important when they have no time to complete what they set out to achieve.

In Bullough et al.'s (1984) study, teachers at an elementary school implementing the Science Research Associates reading or personalized spelling program insert their own curricula. The teachers abandoned the prescribed learning objectives to work on the topics students were interested in. Instead of seeing it as obstruction, this form of teacher

resistance is interpreted as teachers having ‘good sense’ (Gitlin & Margonis, 1995). The findings offers insights into why politically motivated reform tends to remain the same with more changes and what authority relations and work conditions needs to be changed to support the reform.

Giroux (1988) argued Freire’s ideas of resistance and cultural power are applicable in the context of North American schools, saying that resistance is a positive form of power exercised. Resistance occurs in two ways, the inward resistance confronting internalized limitations, and outward resistance toward changing institutional structures through discovering, exploiting, and expanding context-specific possibilities for change (Bullough et al, 1984). Prawat (1991) described inward conversations with self and outward conversations with settings epistemologically or politically as two dimensions of teacher empowerment. Conversations with self is a form of logical self-control enabling one to be more critical of ‘expert’ claims, while conversations with settings enable teachers to deal with social and political oppression against those in power or control. Hence, if the processes in teacher resistance as described by Bullough et al. (1984) are similar to the processes constitutive of teacher empowerment, then I argue teacher resistance can be an empowering process. As such, teacher resistance need not be disruptive and it does not necessarily imply opposition or rebellion to authority or control. Teacher resistance can be productive when teachers engage in dialogue with one another about their work, using the points of resistance as entry points to engage in dialogue about problems, issues, and strategies with others.

To what extent is teacher resistance potentially helpful? Apple (1986) argued teacher resistance of the sort described earlier is not powerful enough. Bullough et al.

(1984) cautioned, “Actions of this kind were common enough, yet they represent only temporary breaks with the prescribed curriculum, to which there was an evitable return.”

(p. 357). However, they added,

The aim of these wayward actions is primarily to make life more satisfying, to give utterance to important but underexpressed values, not to change school in any way. These are not, therefore, radical acts, though certainly their existence suggests there is room for change” (p. 357).

Resistance carries symbolic meanings for people who want to act differently. Sloan (2006) showed in his comparative case studies of three elementary teachers the quality of resistance differed. For example, one teacher resisted the mandate and enacted her student-centered curriculum. Another teacher expressed the mandate was constraining and felt like leaving teaching altogether because of it. However, the quality of this teacher’s instruction was not affected by the mandate. A third teacher rejected pressure to teach to the test, but the content quality of his teaching was low and he loathed teaching.

To understand teacher resistance and emancipatory education, a thorough understanding of cultural-historical and institutional determinants of oppositional behavior is needed to make sense of their actions (Giroux, 1983). The determinants include the context, patterns of interaction, habits, expectations, and responsibilities in which resistance is cultivated (Bullough et al., 1984). Bullough et al., suggested using teacher role as the focus of analysis because it is a point of action for teachers and situates events as produced in institutional structures, social interactions, and consciousness. Role boundaries are framed by ideology—a claim or argument that teacher is a historical artifact shaped by technical value and ideologies of public service—and school structure. Hence, examining teacher role helps us to understand the

context variables, interests, and history; how teacher roles participate in restraining fuller expression of values and desirable goals.

Summary

In this chapter, I reviewed literature on historical trends in science curriculum reform, connecting it to STEM schools for gifted and academically talented science and mathematics students and inquiry science reform. I discussed limitations and gaps in current literature on teachers' curriculum making especially in science reform. I argued for research pointing towards stronger critical views, lenses, and voices, reflexivity, and praxis in research and curriculum making especially in the context of specialized schools with different accountability systems. I also discussed how teacher agency and structure could be viewed as dialectical and reconceptualized teacher resistance as one form of teacher agency that is productive and valuable.

This study, I believe, is novel in teacher-initiated reform of a science curriculum, particularly in the context of specialized schools for gifted or talented mathematics and science students. I want to problematize the words 'agency' and 'structure' a little further using this specialized school context which Daley—highly experienced, qualified, and confident—claimed encourages risk taking, trusts teachers, and is 'different' from other public specialized institutions similar to its kind. Aligned with the design of a case study of a teacher, I purposefully foreshadow teacher agency in the dialectic of agency | structure to value his voice as an organic intellectual potentially capable of achieving goals of reflexivity, transformation, and emancipation through his curriculum work. I center my discussions and analysis on Daley—his work, thoughts, experiences, and practices—exposing conditions in the structures inscribing and circumscribing his

agency. I work with the discourse of possibility and the discourse of critique limiting the former. In Chapter 3, I will discuss critical methods and methodologies coherent with these goals, purposes, and ideas discussed in this Chapter, and methodological issues related to validity claims.

Chapter 3

Methodologies and Methods

Critical Narrative Inquiry

Critical methodologies applied to educational research are used to identify and expose underlying factors or forces in social structures constraining or frustrating educational change and reform. These can be pervasive in curriculum development and teaching but insidious enough to be ignored, neglected, or taken-for-granted by teachers, school administrators, or curriculum legislators. In reading teacher narratives as curriculum makers (Clandinin, 1986; Connelly & Clandinin, 1988), emerging teachers (Bullough, Knowles, & Crow, 1991), and tension managers (Lampert, 1985), I sensed the ‘benignity’ in the descriptions and analysis of teachers’ experiences in curriculum making and teaching. This contrasted from my own experience struggling to reconcile the ambiguities, confusions, and frustrations in dealing with school leaders, colleagues, parents, and students. In this study, I engage critical narrative inquiry to investigate, describe, and analyze complexities constraining what Daley is enabled or disabled to do in curriculum reform in a school context similar to my own.

Narrative inquiry is often adopted as the methodological approach to capture the lived experiences of teachers, students, and other stakeholders through story telling (Connelly & Clandinin, 1988). Lives are turned into stories and the characters and events enliven stories. Narratives are mechanisms and instruments for reflexive research because they draw researchers closer to the subjects’ inner thought processes, decisions, and actions embedded within the messiness of sociocultural and sociopolitical contexts (Tobin et al., 2005). They can be used as a pedagogical instrument to represent teachers’

knowledge and their work (Carter & Doyle, 1995). Teachers can use narratives purposefully in many ways, for example, to draw out their personal curriculum as they learn to become reflective in what they do. The narratives of other teachers can provide provisional models to address their own problems, improve understanding of classroom events, derive new practices, and enhance analytic and interpretive processing skills (Doyle, 1997). They may adjust their practice to match immediate demands or “preserve their commitment to their basic perspectives of conceptions and continue to work out their understanding of teaching from this frame” (Carter & Doyle, 1995, p. 189). Hence, these ‘frames’ are basic tools for understanding the complexity of teaching. They are like paradigms which “define what is recognized as notable in the stream of experiences”, “specify how issues and problems can be thought about”, and “persist even in the face of discrepant information” (Carter & Doyle, 1995, p. 188). Hence, teaching practice is described as living out of one’s narrative of experience, a narrative-in-action, or an expression of biography and history in context-specific situations (Connelly & Clandinin, 1988). These are common qualities of narrative inquiry discussed in the literature. However, narrative inquiry has been criticized for romanticizing experiences, offering interesting stories but suffering from a lack of problematization or critique (Wilson & Ritchie, 2000).

Narrative inquiry can become a form of critical inquiry and critical practice (praxis) when engaged with a critical lens to scrutinize and critique insidious issues embedded in school and classroom systems, operations, curriculum, teachers’ work, and teaching. It also acknowledges teachers as agentic, empowered, knowledgeable, and knowing persons experiencing and exercising agency narratively in character and form

(Fay, 1996). This methodology is coherent with the main principle of *reciprocity* in the dialogic nature of critical inquiry advocated by Lather (1986a). According to Lather (1986a), critical inquiry values the worldviews and emphasizes the experiences, desires, and needs of people who have been oppressed so they are involved in the construction of meaning making and validation of the data in the research process. In examining the contradictions, the oppressed or dispossessed come face to face with how ideologies play out to constrain their agentive power and interests. The dialogic nature of critical inquiry provides mutual educative experience for the researcher and the dispossessed in the transformative or emancipatory process. The process, in which the researcher and participants join in critical analysis and critical action over a prolonged period of time, is self-sustaining.

In their book *Teacher Narrative as Critical Inquiry*, Wilson and Ritchie (2000) encouraged preservice and inservice English teachers to read and write narratives of their own personal histories and ideas. Their personal narratives, when interplayed with Wilson's and Ritchie's narratives written from their experiences in teaching and learning, theories, and research, create opportunities for the teachers to reflect, critique, evaluate, and revise their own narratives. In their reexamination of dominant ideological narratives—related to gender, race, class, ethnicity, power, authority, and meaning of education—shaping their work and constraining their agencies and resisting these narratives, these teachers had opportunities to reconstruct their identities and subjectivities as teachers and as individuals, theorize their experience as a valuable source of knowledge and critical instrument for revising thoughts or reinterpreting actions, and integrate theory with practice. One teacher reexamined and reconstructed his

narratives as part of his reflective practice. The revisions and deconstructions of narratives allowed him to detach from one version of ‘truth’ and re-image his own stories as something better and different from what happened. This enabled him to not subject his students to his interpretations of classroom experience. As such, this teacher had empowered his students to be mentors to construct their own ‘discourse of possibility’. In such a research process, critical narrative inquiry—embodying the qualities of critical inquiry—had evolved from being a research methodology to teacher praxis improving the quality of professional agency.

In this work, I rewrote, re-presented, analyzed, and deconstructed Daley’s and other narratives. This is a powerful means to understanding many aspects of school reform including the problems, issues, explanations, thought, actions, experiences, dilemmas, and tensions. This approach contrasts with inquiry methods using frameworks, surveys, or questionnaires to obtain generalized views for making ‘warranted claims’ to introduce policy changes—something Doyle (1997) described as a “conceptual bankruptcy” model yielding limiting insights into the processes of change in knowledge, experiences, skills, feelings, and practices over time.

A Case Study

In this critical case study of an IMSA teacher’s curriculum reform work, I combine case study methodology that draws on “the particularity and complexity of a single case” (Stake, 1995, p. xi) with critical narrative inquiry to understand teacher agency in curriculum making and teaching within the important context of a specialized STEM school. There are many ways to do case study. I focus on Daley as my case subject as like myself, Daley had tried to create a new curriculum based upon his beliefs

about his students, their abilities, the concept of successful teaching and learning, and purpose of STEM schools. Hence, I am intrinsically interested in the ‘case’ to understand how he manages tensions connected to his curriculum making and context. My purpose is not to draw generalizations to the rest of the STEM teacher population. Rather, I want to engage him as a strong representation of cases and a unique case illuminating what is overlooked in typical cases. In other words, Daley is valued for its uniqueness and commonality. Further, Daley can help me to understand why I experienced tensions and dilemmas in my curriculum making at the Singapore mathematics and science school where I previously taught. I want to discover means and way to address some of the similar problems and issues I had. In this study, I “enter the scene with a sincere interest in learning how they [my case and mini-cases] function in the ordinary pursuit and milieus and with a willingness to put aside many presumptions while [I] learn” (Stake, 1995, p. 1) how the agents or actors enact inquiry-based curriculum reform at a STEM school.

The Case Study Subject

The case subject, Dr Darren Daley, is a white American male in his mid-forties. He completed his undergraduate and Masters degree in Chemistry in a large midwestern university. Later, he obtained his doctoral degree from the same University. He described his training as biochemistry. He had 17 years of teaching experience in high school chemistry. Prior to IMSA, he taught advanced chemistry for 13 years in a Chicago suburban public high school located in what he described as a ‘blue collar town’. In the last seven to eight years in that school, he taught AP chemistry after his school administrator decided to have the science program accredited for AP. Daley reasoned the

‘AP’ label was coveted as a symbol of prestige. Daley first learned about IMSA when he brought his students to IMSA colloquium, an annual event where IMSA students exhibit their Student Inquiry for Research (SIR) projects. The students are mentored by IMSA faculty members, university professors, research scientists from Fermi National Laboratory or Argonne Laboratory, and medical center staff. Daley was intrigued to learn there was such a school with gifted and academically talented mathematics and science students. He applied for the chemistry faculty position when a vacancy became available after an advanced chemistry teacher retired.

Daley worked with three minority female faculty in the advanced chemistry course. Reina was a Hispanic female with a doctoral degree from a large midwestern university. She was trained as a physical chemist and taught previously in a college and bilingual middle school. She had taught at IMSA for eight years. She was the only teacher who student-taught at IMSA and later returned to teach. Alisa is an African American female with a doctoral degree from another large midwestern university. She was trained as a biochemist, worked at the pharmaceutical industry testing drugs, taught in a college and community college prior to IMSA. She had taught at IMSA for two years. Choon was an Asian female with a doctoral degree from the same department as Alisa. She came to the U.S. to do her doctoral degree in chemistry, with specialization in biochemistry. She had taught at IMSA for two years. Prior to IMSA, she had no classroom experience but conducted professional development courses for teachers while working as a research assistant for her doctoral advisor. She adopted the BSCS and ChemCom inquiry curriculum in these courses.

The IMSA science program consists of core and elective courses. All Grade 10 (sophomore) students are required to complete core courses—Methods of Scientific Inquiry (MSI), Scientific Inquiries Chemistry (SI-Chemistry), SI-Biology, and SI-Physics—unless they are placed out the course. There are six elective courses each in chemistry and biology, and eight elective courses in physics. At IMSA, Daley is the lead chemistry teacher for two of the highest enrolled (about 140 to 160 students each year making up 80% of the cohort) chemistry electives—*Advanced Chemistry: Structure and Properties* and *Advanced Chemistry: Chemical Reactions*. As the lead advanced chemistry teacher, he was responsible for leading meetings, coordinating schedules, distributing workload among teachers, and making key decisions on curriculum materials in the course. In addition to advanced chemistry, Daley also taught Organic Chemistry and MSI. He supervised students in SIR projects and served on the student admissions committee.

The Research Journey and Methods

To my knowledge, this is the first study on teacher-initiated science reform in a STEM school. To investigate and unfold the complexities of curriculum making and teaching from subjects' experience, voice, interactions, and operations, and elicit understanding of how tensions form, operate, and penetrate the veins of curriculum making in reform to shape, distort, constrain, and empower, I engage progressive focusing (Parlett & Hamilton, 1976; Stake, 1995) as the strategy in my case study research design.

I began with gathering extensive data detailing all observations. As I observed, I related my observations to my own teaching experiences and understandings, I found

issues, contradictions, conflicts, and tensions embedded in the process of curriculum making and teaching common or unique to this specific context. Problematizing Daley's curriculum reform endeavor to examine his teacher agency in this structure gradually became the focus of my case study. This is appropriate and coherent with my research lens for this study, which is to view inquiry-based curriculum reform as a context-specific emergent social phenomenon offering reconstructed understandings, themes, theories, and explanations. Gradually, I refined my research questions around the data gathered. In the remaining section, I will describe how I developed an interest in Daley's work at IMSA. I will also explain how I progressively focused on issues and research questions based upon new constructed understandings of observed phenomena gained from ongoing data analysis and connections to the literature. My interests and observations dialectically inform my methods, methodologies and theoretical lens.

In this critical case study, I begin with broad and multiple interests in how a U.S. specialized school teacher writes, revises, and teaches chemistry in a socially, culturally, and politically diverse yet similar (in some aspects) context to a Singapore mathematics and science school where I wrote, designed, planned, and taught chemistry. In Chapter 1, I described my prior teaching experience and revealed some tensions I experienced in a different school. Having previously taught strictly to the test in a public school bounded by the national curriculum and examinations, I had no experience (similar to almost all Singapore teachers) in writing, designing, planning, teaching, and evaluating the curriculum. This experience in the first specialized schools for students labeled as gifted and academically talented in mathematics and science proved to be daunting for me and my colleagues who were used to the 'crutch' that the national curriculum syllabus and

predictable examination system offer. As such, IMSA—which this Singapore mathematics and science school was modeled after—provides a valuable and interesting context for me to understand an IMSA teacher’s experience in curriculum reform for inquiry teaching and learning, the issues and problems he had to overcome, and strategies he developed to manage these. This knowledge could inform ways for teachers to reclaim, enhance, and extend their agency in curriculum making and teaching in Singapore and other parts of the world with budding specialized schools.

This study originated in the collaborative efforts of administrators from the College of Education in the University of Illinois at Urbana-Champaign, and IMSA to establish research and internship opportunities for educational researchers, teachers, and students. I became acquainted with Daley at the meetings and negotiated this research opportunity when he said he had proposed reforming the advanced chemistry curriculum. I began this study as a non-participant observer at an IMSA school board meeting I was invited to attend in November 2008. Present at the school board meeting were IMSA teaching and non-teaching faculty members, school administrators, school board members, student representatives, and members of the student alumni. The key meeting agenda was an external science review panel’s (consisting of chemistry, biology, and physics professors) report on the IMSA science program. This external science program review (Handelsman, Shibley, & Wenning, 2008) was conducted once every five years to evaluate the teaching and curriculum structure including content, activities, and assessment. Daley represented the chemistry department to report the review findings. The external reviewers found the chemistry program to have sufficient rigor in testing, but was too content-based, lacked laboratory activities and application to everyday

observed phenomena. They recommended increasing students' engagement through more contextualized discovery learning and less content. These external reviewers' comments and recommendations were coherent with Daley's earlier views on the chemistry curriculum. Daley presented his follow-up plans at this meeting, including his initial proposal to revise the advanced chemistry course making it more inquiry based and less like AP in content and structure. Additional elective courses such as organic chemistry, biochemistry and environmental chemistry would be introduced.

I tracked Daley in the curriculum change process before, during, and after curriculum change. The data collection began in Spring 2009—the last semester of unrevised curriculum—to understand the nature of the curriculum and how it is enacted prior to reform. I observed how Daley taught and interacted with students twice a week in a 95-minute period with the same class of students. He described this group of students as 'average'—not very motivated in learning as compared to previous student cohorts and those in his previous school.

The curriculum and teaching embody Daley's and his colleagues' interpretations, motives, intentions, purposes, attitudes, and beliefs about teaching and learning. I observed students' interactions during class activities such as table discussions and laboratory work. During the class period, I talked to Daley and his students to probe their decisions, thinking, and actions. I made fieldnotes of events, dialogue, interactions, resources, curriculum artifacts, and physical settings of the classroom, laboratory, and school facilities that added to my contextual understanding where reform was taking place. After each observation, I wrote the fieldnotes into descriptive ethnographic reports detailing these information and sequences of events including informal conversations

with administrators and students along the corridor, cafeteria, and dormitories. I also incorporated my personal memos on invoked feelings, thoughts, interpretations, questions, follow-up issues, and comments. Some of these reflections reshaped my research questions and directions. Subsequently, I included additional data collection sites such as the IMSA colloquium and the Intel Science Innovation Award ceremony illuminative of the nature of teacher agency. My residency in the students' dormitories in the first semester helped establish rapport with students, gain better familiarity with the school culture, and insights into students' lives and views beyond the formal classroom and school contexts. These outside classroom experiences added to my understanding of the status of science and science teachers in IMSA, and insidious workings of many diverse factors and forces influencing Daley's and his colleagues' curriculum work. I continued the twice-weekly lesson observations in Fall 2009 and Spring 2010 when the revised curriculum was enacted.

I conducted extensive interviews with Daley, his colleagues, students, school administrators, and a parent over the three semesters. A brief description of the interviews with Daley and my 'mini-cases' (Stake, 1995) in Spring 2009, the interview focus, interview questions, and length of each interview is summarized in Table 1.

Table 1

Summary of interviews with case subject and 'minicases' at the beginning of Spring 2009.

Beginning of Spring 2009							
Subjects	Daley	Students		Parent	School Administrators		School Board Member
		Edward	Lily	Lily's mother	President	Principal	
Description of subjects	<ul style="list-style-type: none"> • White male • Has doctoral degree in chemistry • Has 17 years of teaching experience • Taught at IMSA for four years 	<ul style="list-style-type: none"> • Asian male • Grade 11 student 	<ul style="list-style-type: none"> • White female • Grade 11 student • Her father is a physicist at Fermi Lab 	<ul style="list-style-type: none"> • White female • Previously a school teacher • Currently doing chemical sales 	<ul style="list-style-type: none"> • White male • Has a doctoral degree • Worked at IMSA for three years • Previously a superintendent and principal 	<ul style="list-style-type: none"> • White male • Has a doctoral degree • Worked at IMSA for 24 years 	<ul style="list-style-type: none"> • Asian American male • A principal of a large suburban high school • Served on the school board for 12 years
Interview focus	Background, teaching philosophy, beliefs, theory, reasons for curriculum change, preliminary curriculum change ideas	Reasons for joining IMSA, family backgrounds, interests, future aspirations, IMSA experiences, expectations of IMSA and teachers, comments on the curriculum and teaching, views on AP and inquiry-based curriculum		Knowledge of daughter's learning experience, expectations of IMSA and teachers, views on the curriculum and teaching, views on AP, view on Daley's curriculum change proposal	Experience working at/with IMSA, expectations of Daley and the chemistry teachers on curriculum change, short and long term goals for the school, involvement in the curriculum change, views on the chemistry program and teaching		

(continued)

Table 1 (continued)

Subjects	Daley	Students		Parent	School administrators		School Board Member	
		Edward	Lily		President	Principal		
Sample interview questions	<ul style="list-style-type: none"> • Can you tell me about your teaching philosophy? • Tell me about your teaching experience at IMSA. How is it as compared to other schools that you have taught? • How do you define good/successful teaching or learning? • What do you envision the chemistry curriculum to be in the future? 	<ul style="list-style-type: none"> • Why did you choose to come to IMSA? • Tell me about your experience at IMSA so far. What are some valuable experiences you have gained? • What do you think about the Advanced Chemistry classes? What do you think the Advanced Chemistry class is preparing you for? • How much importance do you place on the AP Chemistry exam? How about your friends and your parents? Why? 	Lily	<ul style="list-style-type: none"> • Lily's mother • What are your views about the nature and quality of education that your child is receiving at IMSA? • The chemistry team is making changes to the advanced chemistry to include more labs, and inquiry in the new advanced chemistry curriculum for next year. (...) What are your views on this? • Unlike most schools, IMSA does not place a heavy focus on AP results. What are your views on this? 	<ul style="list-style-type: none"> • What are some of the short term and long terms goals you have for IMSA? • What are some of your benchmarks on successful teaching and learning? • What was your reaction when you hear about Daley's idea and plans for curriculum change? What expectations do you have for him and the chemistry team? What are some of your concerns? How may these problems or issues be overcome? What kind of support is he given for this endeavor? What role do you play in his curricular efforts to introduce these changes? 	President	Principal	
Duration (minutes)	107 (in two separate interviews)	64	59	28	42	45	34	

I interviewed Daley for about half-an-hour at the beginning of Fall 2009 after he and the three female faculty members spent over 180 hours deliberating the curriculum changes, the teaching philosophy for the course, and rewrote or revised designated units. I wanted to find out what they deliberated over, what problems or issues they faced, how they resolved them, the curriculum considerations they gave when revising, their experience in such a process, and the school administrators' responses to their work. To understand how other teachers involved in curriculum revision experienced the process and understood what Daley wanted to achieve, I interviewed Reina because she and Daley are the only two teachers who taught advanced chemistry in all semesters before and after curriculum change and were involved in the summer curriculum work. Alisa did the summer curriculum work but did not teach the material. Choon did the summer curriculum work and taught it only in the second semester of revised curriculum. After my first interview with Reina and from talking to students, I found Reina attributed a lot of her difference from Daley to her identity as a Hispanic woman and mother. Reina offered alternative views on what partly led Daley to revise the advanced chemistry curriculum—something he did not articulate. According to Reina, her strengths complemented Daley's weaknesses to enable them to share the work in curriculum reform. Although Daley is the key case subject, Reina's, Choon's, and Alisa's identities as female minority teachers from diverse sociocultural and economic backgrounds, working and teaching experiences, and interests in other issues beyond chemistry provide valuable and alternative insights into the culture and politics of curriculum making in IMSA. At the end of Spring 2010, I interviewed all four teachers separately to find out their views after one academic year of curriculum change.

At the end of Fall 2009, I interviewed three other students—Barry (White American male), Snehal (female American of Asian Indian heritage), and Shaquan (African American male)—from Daley’s class. He described this class as higher in ability than the previous cohort and the class I observed in Spring 2009. In the following semester, Daley taught Barry and Shaquan, but they were not in the new class I observed. Reina taught Snehal in Spring 2010. I interviewed Barry individually at the end of Spring 2010 and interviewed Snehal and Shaquan together to draw on their relationship as close friends and minority students in the school. I wanted to engage Snehal and Shaquan in deeper conversations about their teachers, experiences living, studying, and struggling at IMSA, views on the quality of the curriculum, and issues minority students face in relation to gender, class, race and ethnicity—all of which I think have important implications in curriculum making in the context of specialized schools. All the interviews conducted in this study were transcribed. A brief description of these interviews at the beginning and end of Fall 2009, and end of Spring 2010, the interview focus, interview questions, and length of each interview is summarized in Table 2 and 3.

In addition, narratives of teachers’ experiences in curriculum making can also be constructed from document artifacts such as curriculum materials, school websites, brochures, and photographs of the classroom activities, school events, students’ work, and physical settings as these embodied different individual and collective stakeholders’ and institutional values, goals, and beliefs which could direct teachers’ decisions in curriculum making. Hence, these artifacts were also collected as data.

Table 2

Summary of extensive in-depth interviews with case subject and 'minicases' at the beginning and end of Fall 2009.

Subjects	Beginning of Fall 2009		End of Fall 2009			
	Daley	Reina	Daley	Daley's Students		
				Barry	Snehal	Shaquan
Description of subjects	(Refer to earlier descriptions)	<ul style="list-style-type: none"> Hispanic female Has a doctoral degree in chemistry Taught at IMSA for eight years Previously taught in a bilingual middle school and community college 	(Refer to earlier descriptions)	<ul style="list-style-type: none"> White male Grade 11 student 	<ul style="list-style-type: none"> Female American of Asian Indian heritage Grade 11 student 	<ul style="list-style-type: none"> African American male Grade 11 student
Interview focus	Curriculum revision work in summer	Curriculum work in summer, teaching philosophy, teaching experience at IMSA, views on the curricular change	Views and reflections on enacting one semester of revised curriculum	Experience at IMSA, views on the (revised) curriculum and teaching, expectations of the course and teacher, emphasis on AP, suggestions on changes		
Sample interview questions	<ul style="list-style-type: none"> Tell me what curriculum work you did this summer. How was the experience? Tell me about the process. Did any of your ideas and plans change as you worked through this process? 	<ul style="list-style-type: none"> What curriculum work did you do in advanced chemistry? Did you try to make it more inquiry? How was it like? When you were doing this curriculum work, what challenges or problems did you face? What did you hope to achieve from this curriculum change? 	<ul style="list-style-type: none"> How did you find the fall semester? What went well, what did not? Why? Talk about an obstacle you face in your curriculum plans and work? How did you deal with them? 	<ul style="list-style-type: none"> Dr Daley said he wanted to make this current advanced chemistry curriculum more inquiry-based. Is there any lesson that you thought was inquiry based? In what ways was it inquiry-based? If not, what would an inquiry-based lesson be? Can you imagine what are some problems or issues that Dr Daley may face in his role and work as a teacher? How much importance do you place on the AP Chemistry exam? How about your friends and your parents? Why? 		
Duration (minutes)	32	50	30	20	29	29

Table 3

Summary of extensive in-depth interviews with case subject and 'minicases' at the end of Spring 2010.

End of Spring 2010							
Subjects	Chemistry Teachers				Daley's Students		
	Daley	Reina	Alisa	Choon	Barry	Snehal	Shaquan
Description of subjects	(Refer to earlier descriptions)	(Refer to earlier descriptions)	<ul style="list-style-type: none"> • African American female • Has doctoral degree in chemistry • Worked at IMSA for two years • Previously taught in a community college and worked in pharmaceutical laboratory 	<ul style="list-style-type: none"> • Asian female • Has doctoral degree in chemistry • No prior classroom teaching experience • Worked at IMSA for two years 	(Refer to earlier descriptions)		
Interview focus	Reflections on curriculum writing and teaching of the revised curriculum—challenges, problems, issues, and strategies; considerations given to gender, race, ethnicity, and class issues; evaluate successes and/or failures in inquiry change; AP preparation; future actions				Compare two semester of (revised) curriculum and teaching, AP examination preparation, suggestions on improving the course		
Sample interview questions	<ul style="list-style-type: none"> • Tell me something about your experience in this curriculum change process. • How do you think the curriculum change turn out? • What did you see as 'driving' you to do this? • What considerations did you give when revising the curriculum? How did your plans and ideas change? • How did the students engage in the curriculum as compared to previous years? • What do the school administrators hope IMSA students would achieve? To what extent do you think they have met these expectations? • How are gender, race, class, and/or ethnicity of concern to you and the chemistry department? Is it something you would consider in your curriculum work and teaching? 				<ul style="list-style-type: none"> • Tell me about your experience in advanced chemistry this semester. How is this semester as compared to last semester in terms of curriculum and teaching)? • What does it mean to be doing inquiry? Do you see yourself doing any of that? For example? How is that 'inquiry'? • How did you prepare for AP? What did your teachers do to prepare you for AP? Is it sufficient? How important is it to you and your parents? 		
Duration (minutes)	51	38	53	51	14	50 (paired interview)	

In this progressive focusing research design, I began with a broad interest seeking to understand Daley's curriculum reform work in a subject matter I am familiar with and in a school context seemingly familiar yet 'strange' to me. I gradually adopted a narrower critical research lens as I immersed in the setting over a longer period of time, made more critical observations of the phenomena, talked to more people, and scrutinized the document artifacts more critically. My additional knowledge gained from reading critical literature and theories informed my understanding of the observations and other data. These in turn reinforced and confirmed the appropriateness or deficiencies of some theories in explaining the data. As the data collected was (re)written, (re)organized, (re)analyzed, and (re)explained using relevant theories and understandings from prior studies, the issues and research questions were reframed for clarity, new methods and methodologies were chosen, and research lenses revised to better conduct, analyze, represent, describe, and explain the observed phenomena. At this point, I also want to disclose and highlight that embedded in this progressive focusing was a more subtle strategic move to gather data that *detriangulate* rather than triangulate findings as I wanted to expose the contradictions and conflicts in thinking, goals, aims, visions, understandings, and expectations of different people, illuminating tensions and hence emerging strategies under circumstances.

Methods of Data Analysis

In my data analysis, interpretations, and representation, I deconstructed narratives as a set of superimposed and interwoven texts and discourse. Deconstruction is an appropriate analytic strategy in critical research because:

[It] exposes, in a systematic way, multiple ways a text can be interpreted. Deconstruction is able to reveal ideological assumptions in a way that is

particularly sensitive to the suppressed interests of members of disempowered, marginalized groups. In a text, dominant ideologies suppress conflict by eliding conflicts of interest, denying the existence of points of view that could be disruptive of existing power relationships and creating myths of harmony, unity, and caring that conceal the opposite. Deconstruction peels away layers of ideological obscuration, exposing the conflict that has been suppressed; the devalued “other” is made visible. Thus, deconstruction reveals “power operating in structures of thinking and behavior that previously seemed devoid of power relations” (White 1986, p. 421). (Martin, 1990, p. 340)

Narratives as deconstructed texts are never-ending and dynamic as the listener and narrator continually exchange roles. Narratives are also mechanisms and instruments for reflexive research because they draw researchers closer to the subjects’ inner thought processes, decisions, and actions embedded within the messiness of sociocultural and sociopolitical contexts (Tobin et al., 2005). In the principle of intertextuality (Lemke, 1995), meaning making of observations, conversations, writings, and so on can only be understood in the context of other texts and discourse which are characteristic of individuals, communities and subcommunities; cultures and subcultures. All this *messiness* is encapsulated in *heteroglossia*, a word coined by Bakhtin (1981) to mean a complex social system of diverse social relations and ways of speaking:

As a living thing, socio-ideological concrete thing, as heteroglot opinion, language, for the individual consciousness, lies on the borderline between oneself and the other. The word in language is half someone else’s. It becomes “one’s own” only when the speaker populates it with his own intention, his own accent, when he appropriates the word, adapting it to his own semantic and expressive intention. (...) Language is not a neutral medium that passes freely and easily into the private property of the speaker’s intentions; it is populated—overpopulated—with the intentions of others. (Bakhtin, 1981, p. 293–294)

More importantly, heteroglossia also refers to “ideologies inherent in the various languages to which we all lay claim as social beings and by which we are constituted as individuals” (Park-Fuller, 1986, p. 2). This complexity originates in the struggles

between power brokers—those with a stake in a context and who want a voice in its construction—as they exert their power relations to negotiate meanings.

In addition, I analyzed negotiated meanings in teaching as Daley created and manipulated social situations and communities through mediation of conflicting attitudes, beliefs, interests, values, social interests, knowledge, and skills. The transcripts, ethnographic reports, and responses to the open-ended questions in the survey were analyzed using emergent themes, categories, and codes to organize the data for repeated ideas or patterns. I used the weft QDA qualitative coding software to assist me in organizing the data. Categorical aggregation and/or direct interpretations (Stake, 1995) were used. Recognizing that some events will only happen once, I used unique incidence to make direct interpretations.

The second analytical method I used was discourse analysis (Lemke, 1990; 1995; Tobin et al., 2005) which included analyzing words, deeds, values, feelings, other people, objects, tools, technologies, places, and times, sequences, rhythm, unity and others. Discourse analysis is an appropriate analytical tool in this critical research because discourses are intimately linked to the distribution of hierarchical structure in society because control over certain discourses is used to control acquisition of “social goods” (Gee, 1996, p.105) in the society. I analyzed Daley’s and other stakeholder’s different “saying (writing)-doing-being-valuing-believing” (Gee, 1996, p. 154) in the process of negotiating knowledge, social relations, and identities (Apple, 1996) while engaging in specific curricular activities. The discourse analysis also included textual or document analysis of the curriculum materials used as ways to recoordinate or restructure the curriculum.

Methodological Issues and Validity

Although critical narrative inquiry ‘deromanticizes’ teachers’ stories of experience in curriculum making and teaching, it is not immune from some criticisms of narrative inquiry. Writing, reading, and inquiring critical narratives are premised on the assumption that there is reality to be observed in the first place; that reality is momentarily immutable; and narratives ‘capture’ reality. This has raised an epistemological debate on “what counts as ‘truth’” which is not unique to narrative and narrative inquiry. Doyle (1997) argued that stories could offer *possibilities* for ‘truth’ in understanding or learning about teaching for several reasons. If ‘truth’ is interpreted as “an outcome of interaction of theory, observation, interpretation, and scrutiny by an expert community” (Doyle, 1997, p. 96), then it is socially, collectively, communally constructed rather than an outcome of individual formulation. Further, ‘truth’ can be described as having “floating value, akin to a swirl (Geertz, 1995)” —“a literary coming to know with its own special standards of ‘truth’ rather than ‘factual’ rendering of what happened at a particular place and time” (Doyle, 1997, p. 96). Researchers engaging narrative inquiry thus find themselves working in a conflicted situation as they seek to rupture the positivist tradition of truth-seeking, yet bounded by positivist criteria of credibility, trustworthiness, and validity as justifications for making generalizable claims. For example, triangulation to obtain coherence in subjects’ voices and hence greater convergent validity of the claims and assertions (Guba & Lincoln, 1981) is a golden criterion to adhere in qualitative research, serving as guiding post for the living of our lives (Ricoeur, 1992), structures living, and situates one of the narrative whole (McIntyre, 1981).

Narratives, no matter how meticulously told, underplay the lived moment (Sartwell, 2000). The moments lived, sensed, and experienced only serve to provide a limited and temporal plot. As such, narratives have been argued to invalidate life actually lived. The narrator remains distant and the terrains unexplored and inaccessible to some. Having multiple subjects' voice and conduits to voicing thoughts and ideas does not necessarily guarantee balanced views in actual representation as there would always be differential power relations and privileges between the researcher-researched or between the researched who are more dominant or active narrators. When a researcher claims to give voice to subjects, this act of 'giving voice' already subordinates the subjects as receivers of endowed agency rather than self-empowerment. Narrative inquiry into subjects experiences, hence, exposes them to a "voyeuristic gaze of the however-kind-and-empathetic researcher" (Barone, 2009, p. 595) rather than creating socially engaged narratives of struggles (hooks, 1991). However, Sparks (1994) questioned the primacy of narratives from the oppressed, which privilege insider knowledge over the researchers or outsiders. Voices from within provide grounded understanding, but does not eliminate the possibility of reinforcing self-defeating personal tales of disenfranchisement (Goodson, 1995) and hegemonic effects of status quo. Further, these subjects may not have the means, time, knowledge, skill, or interests to create and share these narratives; valuable information or knowledge could be lost. On the other hand, when researchers turn to writing narratives, the continuity between research text and experience may be seen as interrupted.

Richardson (1994), however, sees writing as part of inquiry as the researcher looks inward to reconstruct the experience and project it in writing. The validity of any

research should also rest on the research purpose, design, and questions rather than on a universal or generic set of checklists having little or no relevance to (or which even contradict) the research goal. (I have mentioned earlier how triangulation does not serve my research purpose here.) Hence, claims of validity need not be limited to triangulation (Guba & Lincoln, 1981), construct validity (Cronbach & Meehl, 1956), or face validity (Guba & Lincoln, 1981). Other forms of validity may be more appropriate especially when the genre of the research is shifted. In this study, I find other forms of validity as proposed by Lather (1986a, 1986b, 1993), Hammersley (1990), and Richardson (1994) to be important.

Lather (1993) introduced and discussed how other forms of validities—ironic, paralogical, rhizomatic, voluptuous, and catalytic—are more appropriate for critical research. In Chapter 1 and 2, I mentioned that educational processes are social processes, both are interplayed by complex factors and forces operating through imbalanced power relations complementing or conflicting to introduce complications and obstacles in a teacher's curriculum reform work. As such, the validity of the research could be derived from the success in reconstructing and representing these rhizomatic complexities in the narratives. Richardson (1994) described this 'crystallization' validity—symmetry, infinite mutations, multidimensional, reflecting outward, and refracting inwards—showing not a single truth but providing deeper, complex, and partial understanding of the topic.

Catalytic validity is achieved when the research process "reorients, focuses, and energizes participants toward knowing reality in order to transform it" (Lather, 1986a, p. 272). This is coherent with Freire's (1970, 1985) idea of 'conscientization' which I mentioned in Chapter 1. In this study, I created opportunities for Daley to engage in such

a process by working with him to analyze, reflect, and co-present our survey findings (a separate study from this dissertation which is not discussed here) at the Illinois Association for Gifted Children (IAGC) conference. Daley and I had informally shared our views on the lessons and ways to improvise some of them. Daley initiated writing and administering his own interim survey to find out how he and his colleagues were performing and whether the curriculum was beneficial for the students. At the end of the research, Daley suggested coauthoring a paper with me to publish our research experience and student evaluation feedback on the curriculum and teaching. He also initiated sharing and updating me on future curriculum changes he would make after the first year of curriculum change.

Hammersley (1990) argued that validity of ethnographic studies could come about from its *relevance*. This can also be a form of validity for critical research aiming to empower and transform. I argue that this research has immediate *relevance* to teachers, school administrators, curriculum legislators, curriculum writers, and educational researchers seeking to understand how teachers endowed with good conditions—high qualifications, supporting resources, bright students, and absence of high stake standardized testing—remained challenged in their curriculum reform work and teaching. Hence, in his identity as a (self)-empowered individual and teacher in a specialized STEM school initiating curriculum changes, his narratives offer evidence to debunk misunderstandings or myths about the nature of curriculum making and teaching in such a setting. This opens up minds and new dialogue on teacher agency and identifies appropriate strategies for curriculum change.

Summary

In this chapter, I introduced my case study subject, Darren Daley, the lead advanced chemistry at IMSA. I discussed my methods of data collection and instruments used in the progressive focusing research design grounded and emergent from the findings. I explained why I chose critical narrative inquiry as the methodological approach in this study. I also described how I would conduct the data analysis using deconstruction and discourse analysis; both approaches allow me to tease out the embeddedness of nuanced operations and meanings. I discussed some methodological issues inherent in narrative inquiry and affecting critical narrative inquiry. I also addressed issues of validity in this critical research by drawing on other validities used in critical and ethnographic research.

Prelude to Chapter 4

In Chapter 4, I present my data findings, analysis, and interpretations. Curriculum reform is a complex process swarming with conflicts and contradictions that change agents seek to continually resolve internally and with external elements. The changes do not necessarily happen continuously or even continually; at times returning to start. It became unclear when change had or had not occurred. As I tracked the meanings of inquiry-based curriculum, identified factors and forces affecting Daley's agency to make curriculum changes and effects of these on the curriculum, I realized these ideas intertwined and overlapped. The factors that influenced change could be viewed as discrete but in reality, they were rooted in the same source. They shaped or distorted Daley's curricular decisions, which inevitably impacted how the inquiry-curriculum was designed, and my interpretations of his evolving constructs of inquiry. Categorical

analysis and representation became complex as ideas became recursive, bearing the construct of Derridian deconstruction, where every signifier constantly leads to another signifier under constant erasure.

To make the data more digestible for the audience, I represent my data using narratives as stories to immerse the audience in the data analogous to witnessing a serial event; relating, understanding, interjecting interpretations, empathizing, chastising oneself for doing something similar, scrutinizing, changing interpretations, or casting doubts. I re-presented the data and analysis as staged 'scenes', beginning with the narrative of Daley's educational background, teaching experience, dilemmas, struggles, and turning points to help my audience understand how he became empowered through self and external means to do his curriculum work and teach. Then I made it more personal by drawing the audience into Daley's inner thoughts as he articulated his plans and goals of the revised curriculum, identity, roles, expectations of students, conceptions of successful teaching and learning, and strategies he adopted to push his ideas across to others. In his visions and goals, Daley, once more, reinforced the internalization of objective conditions in the context and subjectivities such as self-identities, roles, motivations, perceptions, understanding, rationale, values, and beliefs about teaching, learning, and academic success. This process of voicing out thoughts was generative of teacher agency. Voicing out is also a means and medium for externalizing thoughts to inform actions when engaged. This sets the next stage to talking about the *habitus* of IMSA, and the constraints Daley experienced while enacting the curriculum reform in this structure.

In Chapter 4, I re-present the analyzed findings using vignettes providing the experiential understanding of complexities of curriculum reform from the interplay of multiple personal, historical, sociocultural, and sociopolitical factors and forces. Some of these vignettes illuminated additional ideas and I discussed these in the interpretive commentary following the vignettes. At times, I kept the vignettes and interpretive comments separate so as not to interrupt the flow and immersion. In some cases, the vignettes and interpretive commentary were better represented by juxtapositions to illustrate and discuss a significant event, activity, or episode, and discussed. At times, I quote discourses generously followed by finer analysis of implicit ideas. I used all of these approaches in Chapter 4 with the aim to provide my audience with the vicarious experiences offered by case studies.

Chapter 4

Findings and Discussion

“Where Plastic Man has his causes, the Autonomous Man has his reasons”

(Hollis, 1977, p. 12)

Daley’s Experiences From the Past

At Lewey High School, Daley taught advanced chemistry to Grade 10–12 students for 13 years. In the first five to six years in that school, he had students do laboratory activities almost three out of five days a week including inquiry. At times when the laboratory did not work, Daley and his students would go off on a tangent for a week or two from the planned curriculum to troubleshoot or problem-solve. He described this as doing “real science”. However, his curriculum development and teaching changed when the school administrators decided to accredit the science program to AP. Daley did not like AP Chemistry because he thought it was too structured or prescriptive in content, type of laboratory, and curriculum hours. The extensive amount of content to be completed rendered direct teaching and drill practices as the most efficient delivery method and means to achieving better scores. However, his school administrators did not consult Daley on AP. Daley gave an anecdotal account of his confrontation with his school administrator,

I have an argument with my gifted coordinator at my old school. (...) They came to me and the administrator said, you now would make it an AP class. I said, “No I don’t want to. I know what it’s like.” He said, “No you will”. I said well I’m an employee and I’ll do that. And I did! (Daley, IAGC conference presentation, February 8, 2010)

Without a choice, Daley taught AP but told Melissa, the gifted coordinator, “This isn’t the right kind of class. We used to have more fun, we have games, we have labs. So now

we memorize”. Melissa rebutted Daley, “Well you have children and when they are in high school wouldn’t you want them to have AP?” Daley insisted, “Not necessarily” (Daley, IAGC conference presentation, February 8, 2010). Daley acknowledged the practical advantages AP perceivably offered. First, it was economically beneficial to take AP, attain a good score for college credits, and save on college tuition fees.. Second, AP symbolized more prestige than an ‘honors’ or ‘accelerated’ label. In recent years, more high status schools have jumped on the bandwagon to accredit their program to AP (Schneider, 2009). As such, AP has become a widely recognized standardized test used for external benchmarking. Nonetheless, Daley insisted direct teaching and drill practices would not interest or motivate high ability, gifted, or academically talented students at IMSA or Lewey High School.

Reclaiming Teacher Agency Through Change

Daley had the opportunity of bringing his Lewey High students to IMSA Alloquium, an annual IMSA event showcasing students’ independent research work to the IMSA and Illinois school communities. Daley did not know such a school existed and was intrigued by the existence of such a school for gifted and academically talented students in mathematics and science. Although Daley had taught at Lewey High School for 13 years and the school had better facilities, he thought, “You don’t teach for the facilities, you teach for the students” (Daley, interview, March 6, 2009). He uprooted himself from his comfort zone to join IMSA.

Having taught advanced chemistry and AP chemistry in his previous school, Daley was designated as the lead advanced chemistry teacher in replacement of one who retired. Daley thought the curriculum would be inquiry based as aligned to the school’s

mission as the “world’s leading teaching and learning laboratory for imagination and inquiry”. However, he was disappointed to find the unrevised advanced chemistry course structured like AP. He said,

My feeling of Advanced Chemistry as it exists now is too structured in terms of trying to cover too much content. Sticking too much to the AP curriculum. Not enough time to integrate ideas, for students to reflect, for students to make connections to biology and physics. And a lot of the lab[oratorie]s are kind of cookbookish, where they get a lot of procedures and just do it. There is not a lot of open-ended inquiry, not a chance for students to make mistakes in the lab[aboratory] to make them want to go back and redo it because we're just constantly moving on. (Daley, March 20, 2009)

Daley wanted more curricular opportunities for students to integrate their knowledge and skills while engaged in open-inquiry. He resisted using the same curriculum, arguing his reasoning based on “research out there” and years of teaching experience. He confidently said,

There is research out there that teaching to an AP test may get a student a five, but it doesn't necessarily interest them or make them really understand how science works. There is a lot of research out there that shows hands-on learning of science specifically is the best way too go about it. Maybe not to get a five on AP tests or standardized tests, but for students to really be in charge of their own learning, of their own understanding. So I've, I did you know, part of it is just me and what I think is right. (...) And so frankly, these curriculum changes came out because I think it was the right thing to do. Is there data out there to back up hands on science lab-based learning? Yes. Did I learn that was the best way in my [teacher certification] methods class? Yes. Does my 17 years of experience show me that students are most engaged when you're doing lab-work? Yes. (Daley, interview, May 21, 2010)

Daley described his curriculum change endeavor as a risk, but he was convinced it was the “right thing to do” and his theoretical and pedagogical knowledge on learning supported his advocacy for inquiry. Daley said his goal to become the best teacher drove him to make curriculum change.

According to Daley, IMSA school administrators supported teachers' risk-taking and change. IMSA teachers were supposed to act on their beliefs, experience, and knowledge rather than follow along others. Especially in his position as the lead advanced chemistry teacher, he was empowered to act on his beliefs. He said,

You know and I'm in a place in IMSA where I get to make decisions based on that. Of course I run it by people. I mean we're supposed to take risks here as teachers. We're not supposed to do what everybody else is doing. And so they encourage us to try things. (Daley, interview, May 21, 2010)

In Summer 2007, Daley approached the IMSA principal and proposed curriculum change. The principal, who had worked at IMSA as a residence counselor, hall coordinator, and assistant principal of 24 years commented that Daley's curriculum change idea would be unpopular to some parents and students. He supported Daley's proposal but said he needed to justify his proposal to the school board and parents.

A timely external science reviewers' report conducted by university science (chemistry, physics, and biology) professors became a valuable supporting document. In the 2008 review, the reviewers observed that the science program had a variety of laboratory exercises across the grade level, sufficient analytical tasks, rigorous tests and quizzes for assessing students' understanding, and appropriately challenging homework. However, less conventional homework tasks, more applicable to real life contexts, less content coverage, and more time for *doing* science were recommended (External Review of Science Programs final report, April 7, 2008). Daley found the reviews to be coherent with his own ideas and used it to support his curriculum reform proposal at the school board meeting in November 2008. The school board members supported his idea. At the curriculum briefing for parents, Daley presented his ideas and reminded parents IMSA

did not offer AP program and hence the advanced chemistry course would also not be an AP course.

Interpretive commentary.

Identifying space in curriculum making. Daley identified space within IMSA to do his curriculum work and teaching. He made a conscious choice through rationalization and reasoning, acting on his beliefs and theories. According to Freire (1985),

Educators must ask themselves for whom and on whose behalf they are working. The more conscious and committed they are, the more they understand that their role as educators requires them to take risks, including a willingness to risk their own jobs. Educators who do their work uncritically, just to preserve their jobs, have not yet grasped the political nature of education. (p. 180)

Daley internalized the objective realities of school accountability to students, parents, and school leaders, but resisted AP because of the limitations he saw in teaching to a structured curriculum. He eventually succumbed to this disempowering and limiting reality because he said he needed to keep his job. Disempowerment, however, did not mean disillusionment; circumscriptions by realities could be temporal with dynamic shifts or changes in contextual conditions, identities, and power relations. Daley kept an eye on possibilities outside Lewey High School. He identified a new unconventional space which he thought could allow him reclaim his teacher agency to teach chemistry through inquiry.

Embodied capital. Conditions were available for Daley to make his transitions from a mainstream to specialized school. This is in part attributed to his embodied social and cultural capital valued as relevant to IMSA. Capital is accumulated labor in objectified and embodied fluid form both inscribed in objective and subjective structures and inherent in the regularities of the social world (Bourdieu, 1986). Daley used his

social capital acquired through networks and connections, and cultural capital accumulated through his doctoral degree in Chemistry, teaching certification, and many years of teaching. In particular, his doctoral degree was a symbolic capital highly valued by IMSA school administrators, parents, and students. It symbolized his professional knowledge, mental acuity, skills, and experience which could be appropriated as ‘transferable’ capital to students. These embodied forms of capital become “social goods” (Gee, 2005, p. 2) when believed and used as a source of power, status, value, or worth. Daley engaged these dialectically to empower himself with agency seeking and making curriculum changes and in the process acquired more capital and social goods to do more.

The Proposed Curriculum Change

Daley regarded science as something different from other disciplines. He said,

I am a science teacher. It may be different in other areas, but science is, is about discovery, and it’s about learning from lab experiences. You know science doesn’t have a book; it doesn’t have memorizing things out of the book. (Daley, interview, March 6, 2009)

Daley felt that chemistry teaching should engage students in laboratory activities and not rote learning. He viewed chemistry books as limiting pedagogical and learning tools.

Daley criticized memorization for the sole purpose of examination preparation. He claimed to do minimal lecturing in the advanced chemistry course and wanted to do less in the revised curriculum.

For the curriculum change, he “envision[ed] the curriculum becoming more lab-based, more inquiry-based, more connections to biology, biochemistry” (Daley, interview, March 20, 2009). He wanted it to be “thematic”, where “a whole semester can be based on doing reactions” (Daley, interview, March 20, 2009). In this way, students could develop a “mosaic conceptual understanding of the links between chemistry,

biochemistry, organic chemistry, biology” (Daley interview, March 20, 2009) and not learn chemistry as topical units. His revised curriculum goal was “to have students really understand more, the big concepts, and big pictures of chemistry and how they link to the big concepts of biology and link between biochemistry” (Daley, interview, March 20, 2009) and emphasize less on problem-solving for AP examination.

Daley believed inquiry curriculum was not exclusive for gifted or IMSA students. He believed inquiry was possibly the best possible way of learning science coherent with constructivist view of learning through construction of meaning through students’ questioning and independent discovery. He said, “I want the chemistry program to be more of an open-ended inquiry lab-based direction and if our AP scores go down because of it, so be it. It could go up because they become more interested” (Daley, interview, March 6, 2009). Hence, AP scores did not necessarily correlate with inquiry-based teaching and learning. However, Daley clarified he did not mean that IMSA curriculum was better than AP. Rather, the didactic mode in which AP had to be taught in order to ensure content coverage made learning unengaging for IMSA students. Gifted students, in particular, did not like to be taught using PowerPoint slides but rather they like to reason and learn in context. He said,

These students really, you know in my time in IMSA, and with the more gifted students in my previous school, gifted students really really really want things to be taught to them, they want to learn things in context, they want to have a reason to learn it, **more** [Daley raises his voice] I think, than a typical student. (Daley, interview, March 20, 2009’ emphasis added)

Daley noticed that some students did not get A’s for IMSA courses or five’s on the AP examination because they had interests and devoted time to other things. Hence, the grades might not accurately reflect students’ ability.

Daley carefully articulated his vision for curriculum change to make it coherent with institutional goals. He said,

You know the whole IMSA idea really, the SSLs; what really is different about IMSA's philosophy, and I go along with this philosophy, and this is probably another reason why I came here. The philosophy is that we want students to learn how to [Daley points his finger to the head]. You know it's not just learning calculus, physics, chemistry, but how to become lifelong learners, metacognitive, be metacognitive, improve their metacognition skills. That's what makes IMSA different. (Daley, interview, March 6, 2009)

Metacognition is "learning how to learn" (Daley, interview, March 6, 2009) which is an indisputable quality of good learning and advocated in IMSA's mission. In the revised curriculum, Daley wanted students to achieve metacognition through the analytical process of learning. He saw this as more important than compartmentalizing learning into separate subjects.

Daley's curriculum change plans would be carried out according to what he thought was "right" and beneficial for the students as opposed to developing it around the students' abilities. He saw the responsibility of IMSA teachers was to not to provide students with facts, but create appropriate contexts for students to construct their own knowledge and make sense of what they were learning through laboratory activities. Students were responsible for interactive engagement. Daley once commented he had the best and worst classes in Spring 2009 semester. I asked if he taught both classes differently. He said,

Yes, I use more examples in that class and show them how to solve rather than have them present in groups like this. But there is limited time. We meet twice a week and there is lab-work to do. I cannot give too many examples. They can look for me after class. You know, this is IMSA. (Informal conversation in Daley's lesson observation, February 17, 2009)

I clarified with Daley what he meant by “This is IMSA”. He replied, “They chose the school, they chose to come here. At least this is what I believe” He rested his back on the side bench with arms crossed. He argued that students chose to come to IMSA and were gifted; hence, they should dutifully work hard to meet his expectations.

Daley expected students to be responsible for their own success; successful teaching must be accompanied by students’ ownership, self-discipline, and motivation to learn. Daley reiterated that students should “[L]earn more on their own. They are really supposed to be learning by asking questions and thinking through things, integrating ideas” and “constructing the meaning and analogy on their own from their questions, and taking their misconceptions and replacing them with correct idea”. He added, “We believe they have to do it, we can’t do it for them” (Daley, interview, March 6, 2009). Daley “believe[d] a hundred percent (...) that students learn best by struggling and being frustrated. Not completely frustrated because they will shut down” (Daley, interview, March 6, 2009). Students were responsible for constructing their own learning and make meaning out of the “puzzles” to form a “big picture” (Daley, interview, March 6, 2009) understanding of what they are learning. When students faced difficulties, they were expected to take the initiative to approach Daley or their peers for help. Daley reasoned some IMSA students who were used to being “spoon-fed” (Daley, interview, March 6, 2009) with information, memorized and regurgitated facts, would not thrive well in IMSA.

Interpretive commentary.

Broad and ambiguous goals. Daley talked about having a laboratory-based and inquiry-based curriculum for student-centered learning. He reiterated these ideas at the

school board meeting, in his interviews, and conversations with school visitors, students, and parents. However, he did not explicate what each of these terms meant, how he intended to bring these ideas into his practice and curriculum writing, what his ideas looked like in actual teaching, what problems or issues he anticipated and how he would address them, and how he would assess students' learning and self-assess his teaching. These issues remained unaddressed or ambiguous before his summer curriculum meetings and gradually took form and substance in the process of curriculum writing, enactment, and reflection. Curriculum reform would become substantive and 'real' only in the *process* of actively thinking and performing actions for change. This implied that the actual changes and outcomes of curriculum reform could not be expected to be the same as intended, thought, or planned. The initial ideas must be tested and contested; the objectives, means, and outcomes may be modified; and a host of factors and conditions must be considered in curriculum making. This would be illuminated in the later narratives.

Identity and subjectivity. Teachers' agency embodies multiple identities, and constructed subjectivities in relation to self, subject matter, students, and social milieu (Schwab, 1959) in curriculum. The identity of a subject is viewed as rational, unified, singular, simple, autonomous, and consciously self-chosen, while subjectivity is associated with the postmodern idea of individuals being social constructed, complicated, fragmented, contradictory, and fluid (Ritchie & Wilson, 2000). Daley embodied and enacted both at different times and in various contexts. His identity as a committed teacher and curriculum reformer was illuminated as he exercised and projected his personal commitment, beliefs, values, knowledge; became more willing to take risks and

be professionally vulnerable (Lasky, 2004). The embodiments of his identity interacted with contextual factors and forces, forming his subjectivity. He aligned his curriculum change goals closely to IMSA's mission to reinforce his justification of his call for change. This was also a way of legitimizing his role, the importance of this reform, and to justify his plans, making it difficult for other stakeholders to dispute or disagree. At different stages of the curriculum reform process, this subjectivity settled to become more stable as his reconstructed identity. This assumed a cyclical process of moving from identity to subjectivity to reconstructed identity.

Hubris in teacher agency. Daley's teacher agency entailed a hubris emanating from what he articulated as his reason for making curriculum change, how he carried it out, his expectations of students, and implicitly higher status of IMSA. Daley carried out his curriculum work based on what he thought was good for the students and high expectations of them. Students were made accountable for their own learning and meeting his expectations. Daley's comment "This is IMSA" implied the distinguished higher status of IMSA as compared to other schools and hence justifiable high expectations of students. Students should be capable of meeting the mark and earning their keep in this prestigious institution if they put in hard work. Even though Daley tried to suppress his hubris by saying he did not claim IMSA curriculum to be better than AP, contradictory nuanced meanings in his words at times suggested otherwise.

Daley viewed IMSA as a prestigious and elite institution. This hubris, embedded in his teacher agency, inherently drove him to propose and carry out curriculum change. The quality of hubris in his teacher agency was captured in nuanced ways on several occasions and by things he said. For example, Daley (and Choon) suggested some

students came to IMSA to get good testimonials for college, implying the credentials and value of the schools' reputation. When I asked him to comment on differences between cohorts of students. He asked, "You're talking IMSA versus IMSA?" implying the difference between students from IMSA and other schools. In an earlier quote he said, "This is IMSA" and "That's what makes IMSA different" implying IMSA is a prestigious, distinguished, and elite institution different from others. Daley also said that at IMSA they "[T]each here without teaching. You know, we don't directly provide them with a lot of information. We provide the atmosphere enough to learn it" (Daley, interview, March 6, 2009). This ironic phrase implied that teachers did not have to spoon-feed students as they were capable enough. In one lesson Daley said, "There's a smart way to doing this. And a not a smart way of doing this. I didn't say we're not smart. We're IMSA. There is a smart way and an efficient and not so efficient [way]." (Daley, lesson observation, September 14, 2009). Being a member of IMSA meant doing things intelligently with thinking, elegance, and poise. Clearly, Daley placed highly IMSA's status above *others* and naturally raised the bar of his expectations for students.

Teachers at IMSA valued the label of elite and excellence. Daley once visited the Central Intelligence Agency (CIA) on his trip to the NCSSSMST conference in Washington DC. He recounted his experience to the students and shared with them, "CIA really wants people like us who are good in math and science in the intelligence community" (Daley, lesson observation, March 17, 2009). The phrase: "CIA wants people like us" collectivized Daley as a member of this elite group sought after and highly valued by society; it also revealed Daley's hubris.

Daley's sense of hubris was not isolated. Choon, who taught for only two years, also exhibited some of this quality. She said, "You need to think if you're at IMSA". Choon elaborated, "If they [students] struggle a little bit, I expect them to work on their own and try it" (Choon, interview, May 7, 2010). Silvra, a student in Daley's Spring 2009 class said they learned mostly through laboratory work. Below was how she described her laboratory experiences:

I like them because it's really hands-on and interesting. Sometimes I don't understand what is discussed in class, but with the lab, I understand better. This is what we do very often in IMSA. This is how we learn in IMSA. We have a lot of hands-on. (Daley's class observation, March 17, 2009)

Silvra expressed her liking for laboratory activities, which was something they did "a lot" at IMSA to reinforce understanding of the theory through practice. Evidently, she identified closely herself with the institution as though she was the spokesperson of the student body. A strong sense of pride in her school was projected.

Although the quality of hubris might be regarded as an embodiment of teacher agency, it was significant not only as constitutive of it, but as power or strength for reclamation or generation of teacher agency to initiate and make curriculum changes. Daley strategically applied it in various ways. First, he drew on this hubris to distinguish IMSA from *other* institutions, and IMSA students from *other* students to justify the imperativeness of curriculum change. He said,

You know they [IMSA students] could have stayed at home and taken an AP class and get their 5s and they are valedictorians. You know and they come in and they are surrounded with kids who could have been all valedictorians essentially. And so I put this up because if I were to go work there and teach advanced chemistry, I need to know what our mission statement is and know what we're supposed to be doing and the kind of environment we're supposed to be creating and to me a drill oriented curriculum wouldn't do this. (Daley, IAGC conference, February 8, 2010)

Daley associated AP closely with “drill oriented curriculum” to mean it was routinized and unchallenging for the students. He used Torrey High School—a high performing and internationally known U.S. high school—as a counterexample to IMSA:

I can tell you right now when I was at the NCSSMST conference, the principal of Torrey, one of the best academies in the country, like ours. It’s an academy somewhat like ours. He said it was a great idea, but we’re all about AP scores. You know, we can never let it happen. So there’re schools that are dead set against it... It [Torrey High School] fulfills more, I think what’s a typically, and I think they call themselves as... it’s more a typical college prep, that the idea is to get the students AP scores. (Daley, interview, March 20, 2009)

Although Torrey High School was highly ranked, Daley thought it was a “typical” high school as it offered AP program. IMSA was different from Torrey. Daley claimed that he “doesn’t really care” what students scored on AP because they “don’t teach to the test at IMSA” (Daley, informal conversation, February 24, 2009). As compared to students trained in regular AP classes, he thought IMSA students had performed reasonably well. The students agreed that Daley and the other chemistry teachers did not teach to AP and they had to pick up study guides to practice on their own or fill some knowledge gaps.

Second, Daley’s hubris was of the ethos of elite institutions and its members which wish to have the reputation of high standards. He acknowledged members of elite institutions were arrogant. He described Torrey High School as a “snobby place” (Daley, interview, March 20, 2009) where people are also arrogant. He felt people at IMSA are arrogant too. He said, “You know when you work in an academy like this, you think you’re great!” (Daley, interview, March 20, 2009). At the IAGC conference, Daley said,

Anyway, here is our mission statement. It’s very arrogant, the first sentence and the faculty despise it. “The world leading teaching and learning laboratory for imagination and inquiry”. And the faculty really didn’t want that in there. A lot of the faculty, because it sounds very arrogant. Does it not, in my opinion? And then the administration said, no no no no no, we mean we take the lead, we don’t mean

we're the best necessarily. We mean we want to be innovative and take the lead. Well, I think it's arrogant. (Daley, IAGC conference, February 8, 2010)

Daley acknowledged hubris or arrogance as a fact, reality, or controversial demeanor which elite institutions espoused or emanated in speech or actions. He cleverly used this institutionalized hubris to his advantage, warranting his proposal and actions to contest the AP curriculum. He questioned its appropriateness for gifted students.

To stretch this point further, I argue that by taking on this challenge to initiate and implement curriculum reform for his department, Daley concretized and elevated his position in multiple ways as an educator outside and within the school. People at IMSA and especially specialized schools in the NCSSSMST community paid attention to what he was doing. According to Davis (2002), "One's status can determine the kind of activity in which one is permitted to engage and the extent of one's voice, decision-making, and power within educational and professional contexts (Davis, 1999, 2000)" (p. 8). Hence, Daley's status as the lead advanced chemistry teacher, an IMSA teacher, and highly qualified teacher was important and enabled his construction of voice and presence. His success or failure had important political ramifications because he was contesting the quality of other STEM school curriculum, and hence the schools' adequacy in addressing the needs of gifted mathematics and science students.

Although elitism often invites condescension, I argue that intellectual elitism could incite teachers to engage in school-based curriculum reform and schools to reexamine their curriculum. STEM schools are not subjected to high stakes testing and hence have more curriculum flexibility. In questioning his own chemistry curriculum, Daley had raised other STEM school teachers' and administrators' attention to rethink their school curriculum quality. Policy makers who evaluate STEM schools' efficacy in

addressing the mandated charges might also be interested to know if the curriculum is keep up-to-date with the latest thrust in scientific and educational research. To make the curriculum reform successful, Daley must be highly vested in his beliefs and be able to exercise his agency in decision-making. However, having agency alone was not enough as Daley's teacher agency was shaped, enabled, distorted, and undermined by the institutional structures. In the next section, I discuss a macrostructure which I call 'the habitus of IMSA'.

Habitus of IMSA

Daley's teacher agency was circumscribed within the structure or habitus of IMSA simultaneously enabling and constraining his ability to act through covert and overt means. According to Bourdieu, this structure encapsulates "durable, shared body of dispositions, classificatory categories, and generative schemes" (Jenkins, 1992, p. 49) constitutive of its habitus. The habitus of IMSA was shaped by objective realities connected to history, sociopolitical, socioeconomic, and sociocultural factors and forces giving IMSA its existence, present form, and being. This habitus embodied the primary and secondary structures proposed by Giddens (1979, 1981), which I had mentioned in Chapter 1. The primary structure entailed forms of power exercised by those with the knowledge of the agenda and operations of specialized institution to justify the existence of such a school in the Illinois community. They believed having STEM schools tapping on gifted and academic young minds was a means to address the issue of deficiency of scientists, mathematicians, and engineers. A secondary structure was related to the make up of chemistry as a discipline which Daley argued was only content specific having no relation to social issues. Collectively, these two resistant and pervasive-in-thought- forms

of structure made up the overall habitus of IMSA. In what follows, I discuss both types of structures in IMSA.

The primary structure. The history, organizational hierarchical structure, availability and access to resources, systems of accountability and control, and school curriculum were constitutive of the primary structure of the habitus of IMSA. As mentioned in Chapter 1 and 2, the government report, *A Nation At Risk* (NCEE, 1983), made a significant impact in the history of American education. In this report were calls for high schools and colleges to supply students for high-tech jobs in STEM to enhance the country's global competitiveness. In the 1980's, Illinois experienced brain drain to springing high-technology industries in California, Texas, and Southwest states. Local industries, especially those at Fox Valley Illinois, were looking to revitalize the economy of the state to prevent brain drain and closure of companies. Illinois contested Texas for a huge federal contract to build a superconducting supercollider. An idea in the proposal for the contract was the establishment of a school to house and educate the scientists' children. At that time, influential public figures including Leon Lederman—Nobel Prize Winner who later became the director of Fermi National Accelerator Laboratory expressed concerns over unaddressed needs of gifted children. He argued that gifted children could become an important source of untapped talented minds. These different historical and political events collectively drove the process of IMSA coming into existence.

Systems of control in schools resemble private-sector organizations and are literally political institutions because of the structure, decisions-making process, and unequal distribution of power based on social power relations (Sarason, 1996). State

government is no less political than local government and invested in power conflicts and struggles. Members of school boards elected or appointed have political loyalties and differential powers. The superintendent, chosen by the school board develops his or her own powers within the state board, school system, and sectors of the community to exercise influence. The habitus of IMSA, epitomizing a highly complex organizational system, preserved institutional order for accountability through vertical and linear systems of control. At the top of the hierarchy was the Board of Trustees consisting of 17 members (IMSA, n.d.)—13 appointed voting members representing significant organs of the Illinois community including the scientific community, private industrial sector, general public, Higher Education, and a mathematics or science teacher; four positional non-voting curriculum legislators. The Board selected and evaluated the IMSA President overseeing the administrative matters such as school funding and accountability. The IMSA principal's job scope was more academic as he took charge of the employment of teachers, evaluation of teachers, and students' academic performance. Beneath the principal were program coordinators and teacher faculty in the academic organ. This is a common organizational structure in schools. Social agents at the top of the hierarchy having broader knowledge of the social and political agenda were tasked to determine institutional goals and directions to direct what agencies lower in the hierarchy should and were able to do. Their knowledge became their power which in turn generated more knowledge to act (Foucault, 1977). This power, according to Foucault (1977, 1980), was both repressive and productive.

The operations and workings of IMSA were largely shaped by its two charges. Beyond its academic responsibilities to a specific group of Illinois children (the first

charge), IMSA's second charge was met through the efforts of its non-academic organ in charge of outreach programs such as problem-based learning (PBL), IMSA Kids Institute, and Excellence 2000+ courses for students and teachers after school or in summer. The academic and non-academic organs essentially functioned independently; and the teaching and non-teaching faculties performed different roles. To demonstrate its accountability through the second charge, the habitus was in part sustained by continual and purposeful projections of positive images of the school's, teachers', students', and program's achievements and contributions. In 2009–2010, there were at least 27 posts on the school website. For example, IMSA had reportedly received \$75,000 grant from Motorola Foundation to support IMSA's PBL initiatives to conduct professional development courses for teachers across the state. It won the top National Intel Star Innovator Award for Science excellence, beating six hundred over schools across the nation. The students received the highest ranking in the International High School Mathematical Contest in Modeling. All the news contributed to the school's image of excellence and success.

Admission to IMSA was challenging as typically over 600 students would apply each year and only approximately 200 of them would be accepted. Applicants to IMSA had to submit their SAT Reasoning examination score, academic records, teacher recommendations, and an essay describing themselves and their interests in mathematics and science. The students' incoming scores for SAT and ACT scores were always above national averages. This information, available on the school website and brochures, created symbolic images of institutional excellence, exclusivity, and success constitutive of its habitus.

Monitoring, surveillance, and evaluative mechanisms and instruments were used to ensure accountability. According to the principal who said,

We have a system in place called ‘CADRE’ that assigns every teacher new to IMSA an instructional facilitator and that person is the supervisor. They write the formative assessment, the summative assessment. The system is designed to be teacher-to-teacher. Every first year teacher has a mentor. Every teacher in years two, three, and four has a collegial support team—three other teachers in addition to instructional facility. So it is designed to, in some ways, the administration, you know, technically I supervise every teacher on a continuing contract, so thirty some odd teachers. Maybe forty, so you know, how much time and energy do you have when you have thirty to forty teachers that you supervise along with other direct reports. (IMSA principal, interview, May 14, 2009)

CADRE—the acronym for Career Development Reinforcing Excellence—was a system of professional accountability and development for teachers grounded in mutual accountability and professional trust. It was a mechanism of quality assurance used to monitor, evaluate, judge, manage, and control the quality of curriculum and instruction holding teachers accountable to improving student learning and professional practice, and developing products and services for community outreach (IMSA, 2010). It facilitated the teacher’s immersion into the institutional standards and culture and directly served the principal. Realizing the difficulty of managing every teacher on his own, the principal distributed this power along the lineage of authority to experienced teachers so that they became his extended surveillance conduits and instruments to monitor the new teachers. This power could be productive as he empowered himself to perform more tasks and attend to more pertinent issues needing his direct attention. In delocalizing this power (Foucault, 1977), the nature of teacher agency was also changed. When more experienced teachers such as Daley became teacher mentors, they would regulate their own behaviors to ensure better role modeling and professional development as leaders. Further, peer

professional evaluation was believed to be less intimidating, and hence could promote reflections and collegiality among teachers as they learn from one another.

The habitus of IMSA was constraining and enabling at the same time. The principal argued that Daley was supported to do his curriculum reform work in many ways. For example, he said Daley and his colleagues were paid to do their curriculum reform work in summer. Daley could work in consultation with his colleagues, most of whom had doctoral qualifications and prior teaching experiences. The school could purchase new textbooks and other materials if Daley needed them. Daley had fewer teaching hours compared to teachers in other public schools. The science laboratories and research laboratories were well-equipped with instruments—some rarely available in schools. The principal thought that these were favorable conditions supporting Daley’s endeavor.

However, Daley felt he was often too busy during the semester to make any curriculum changes. He only had time to implement them. Further, he felt the curriculum structure was too restrictive. First, the science program was structured as separate disciplines—biology, chemistry, and physics. Advanced chemistry was taught twice a week for a 95-minute period. He felt there was not enough curriculum time, each period was too long, and infrequent class periods became problematic when students missed class.

The school administrators had curricular goals similar to Daley’s ideas and this was important in facilitating the curriculum reform work. For example, the principal’s idea of AP was coherent with Daley’s. He said,

You know ten years I’ve been in this job, I don’t feel that I’ve gotten a lot of pressure like “Why aren’t you teaching more AP”. I think we just say, “We teach

the curriculum.” Why? Because we believe that when we say we want to create “creative ethical scientific minds that can advance the human condition”. Part of that kind of mind is kind of represented by the Standards of Significant Learning. We’re going to design courses, we’re going to make it more lively, and kids are going to develop those habits of mind. We believe that the way to do that is through learning experiences that are, inquiry based, problem-centered, and integrative. So how do you do that? That AP curriculum is not those things. (IMSA principal, interview, May 14, 2009)

The principal added, “We say we want to be a teaching and learning laboratory right?

That in itself says to me you need to try things” (IMSA principal, interview, May 14, 2009). Daley articulated many of these ideas about AP and what IMSA should be doing for students.

The President of IMSA envisioned packaging and exporting some of the good practices, lesson plans, and programs to the public. He called IMSA an “outlier” (IMSA principal, interview, May 26, 2009) and projected a very strong sense of pride in IMSA serving as a model for others. As a residential school, parents appeared to have minimal influence in the operations of the program. The President commented he had very little interaction with parents except for those occasional encounters in the parents support group meetings. He did not think parents would have significant influence on the curriculum because they did not have the expertise and curriculum writing was something for the experts—the highly qualified IMSA teachers.

In sum, the primary structure of IMSA was shaped by the sociopolitical and sociocultural factors and forces connected to the historical events and political purposes of having such a school in Illinois. Therefore, Daley’s curriculum reform work was embedded in politicized context made up of complex systems of accountability to parents, students, school administrators, and broader institutional accountability to the schools’ mandated charge.

The secondary structure. The structure of chemistry as a discipline was also constitutive of the habitus of IMSA. In the science program, chemistry was taught as a separate discipline from physics and biology. ‘Inquiry-based’ chemistry, physics, and biology courses were taught in the first year (Grade 10) and form the core courses. The advanced science courses were elective courses that students could take if they decided to major in the discipline. An example of this would be the advanced chemistry course—a two-semester course which most IMSA students would take if they intended to take the AP Chemistry examination at the end of their second or third year.

The advanced chemistry course was the secondary structure within which Daley’s curriculum change work was embedded. The course was designed to be taught in sequence of individual topics such as stoichiometry, chemical reactions, chemical bonding, gas laws, kinetics, electrochemistry, thermochemistry, and acids and bases. This structure reflected the typical chemistry syllabus in AP and introductory chemistry college courses, which contradicted Daley’s idea to integrate the learning of chemistry with other science disciplines, and learn chemistry thematically such as environmental science and medicine.

In addition, the secondary structure also included the quizzes, tests, examinations, graded laboratory reports, and assignments. These were conventional instruments and mechanisms teachers used to monitor students’ effort, work, and understanding. It also served to evaluate their own teaching efficacy and benchmark against other teachers for accountability.

In sum, the primary and secondary structures were constitutive of the habitus of IMSA. This habitus embodied many elements shaping Daley’s curriculum change work

and causing tensions. Daley described his curriculum making and teaching as “walking a tight rope”, a metaphor reflecting confusing, contradicting, and conflicting feelings, emotions, thoughts, and experiences. In the next section, I present several vignettes and provide my analysis of his high-wire walking experience to offer rich, deep, and vicarious understanding of his curriculum reform experience at IMSA.

“Walking a Tight Rope” in Curriculum Making

In exercising his teacher agency, Daley’s experienced “walking a tight rope” as he managed tensions presented by contradictions and conflicts between the ideal and realities of specialized school context. He had to manage macro ideologies of STEM education embodied in the larger habitus. While the habitus of IMSA was pervasive, dominant, powerful, empowering, and constraining at the same time, Daley resisted some of the status quo of this habitus to introduce some disruptions. His discontent with the previous curriculum resulted in dissonance and resistance to use it further. He adapted human and non-human resources available in this habitus. He assessed the transposability (Bourdieu, 1977) and extendability of his mental schema on teaching and learning to the context of IMSA based on his knowledge of students and the sociocultural context. I teased out some of Daley’s schema and how he justified its applicability and appropriateness in the context of IMSA as he learned to perform his high-wire walk.

Vignette 1.

Good teaching is walking the tight rope appropriately, always thinking about what you’re doing, and saying that didn’t work, but it’ll be different the next time I give them. I’m going to figure it out next time and creating an environment in which they feel like they can ask questions and learn. (Daley, interview, March 6, 2009)

Teaching is learning to make balanced and informed decisions on how much content or facts to give and how much time to spend on developing metacognitive skills or allow students to struggle on their own. Daley metaphorically described his struggles, dilemmas, and challenges in curriculum making and teaching as “walking a tight rope”. Daley thought the nature of high-wire walk changed with the nature of students and contexts. He said, “[T]he challenging part of good teaching is, where that tight rope exists is different for every kid in the room” (Daley, interview, March 6, 2009). At his old school, he said he would “err on the side of spoon feeding too much” because of the school he was at (Daley, interview, March 6, 2009). However, “At IMSA, I probably, if I’m going to err on either side I would err on the side of making them figure out more” (Daley, interview, March 6, 2009). Daley acknowledged nobody walked the tight rope perfectly and it required constant thinking to walk it well.

Daley did not believe in taking extreme approaches, but strove to take a balanced approach. He said,

You know, one end of the spectrum would be oh I just want my students to memorize a bunch of stuff and spit it back to me, regurgitate on a test and get their A. And the other end will be complete, oh I’m never going to give a test, it’s all about the process, we’re always going to be in the lab. There’s there’s somewhere in the middle to me. (Daley, interview, March 20, 2010)

He did not claim to know everything about inquiry and believed nobody was an expert in it. He strove to stay on the tight rope by taking a middle stance—focusing on testing, content teaching, and laboratory activities at the same time.

Daley said to be successful in teaching was to be able to answer students’ questions but not spoon-feed them. His role was to provide learning opportunities, in particular, laboratory experiences for students. An environment that was conducive was:

[A]n atmosphere where you are kind of throwing things at them, giving them ideas, but not explaining it all. Lots of lab activities, trying to ask them questions, to link what they're doing in the lab, what we talk about, discussions, demos, book readings. (Daley, interview, March 6, 2009)

Daley was trained as a biochemist so he wanted to create integrative learning experiences especially in biology and chemistry. He thought teachers could explain the major important concepts and address students' questions. However, he was against the idea of lecturing and teaching students problem solving step-by-step. He said, "Good teaching is not explaining everything perfectly" (Daley, interview, March 6, 2009).

Daley justified his proposal for curriculum change as coherent with IMSA's mission especially in his interpretation of the term 'laboratory'. The complete school mission statement is quoted below:

The mission of IMSA, the world's leading teaching and learning laboratory for imagination and inquiry, is to ignite and nurture creative, ethical scientific minds that advance the human condition, through a system distinguished by profound questions, collaborative relationships, personalized experiential learning, global networking, generative use of technology and pioneering outreach. (IMSA, 2009a)

Daley described curriculum change as analogous to experimentation, and IMSA was like a science laboratory:

IMSA is a laboratory for teaching and learning. That's what it's supposed to be. That literary means try things, and if IMSA is a laboratory, that means changing the curriculum is an experiment. And not all experiments work. The beautiful thing is that this class, if we think we need to move back in the other direction a little bit again, we will. And that won't cost me my job. It won't hurt students. It's the kind of the thing we're supposed to be doing here. This is what we're supposed, we supposed to be trying out. (Daley, interview, March 20, 2009)

Drawing the analogy between IMSA as a laboratory and the scientific laboratory, Daley claimed to have the space and autonomy to test out his ideas, take risks, and reverse his decisions if the new ideas did not work out.

Interpretive commentary for vignette 1. Daley distinguished the nature of high-wire walking at Lewey High School and IMSA. The two sides of the high-wire were symbolic of dichotomous choices between content teaching | teaching for metacognition, direct teaching | teaching for understanding, and AP curriculum | inquiry or laboratory curriculum. Teaching at IMSA meant erring on the right of each binary; these qualities distinguished IMSA from other mainstream public schools. Daley recognized the high-wire walk was contextualized and unique so he had to constantly make adjustments based on the conditions, basing his decisions on perceptions of students' abilities (and hence his expectations of students), contextual demands, and constraints. Daley said he aimed to balance in the middle, but he did not explain *how* this could be achieved in reality. How would answering students' questions without spoon-feeding them with information look when faced with time constraints? How would good teaching result from imperfect explanations?

A scientific laboratory is a space for experimentation into unknowns. Daley saw IMSA as the space for inquiring into and carrying out trials on new curriculum and pedagogies. Nonetheless, an institutional space is a social space with complex social networks where individuals and groups exercise asymmetrical powers in visible and insidious forms to achieve different agendas. A school space is thus less fathomable than a scientific laboratory where experiments are designed with known variables held under controlled conditions. Scientists can apply theories or laws to predict and explain the outcomes of experiments or generate new ones based on a set of assumptions. The observed phenomena, explanations, theories, concepts, and laws could be generalized and applied to other contexts because non-human objects do not behave, react, or respond

with a mind of their own. Scientists can repeat experiments until desired, replicable results are obtained or fit into theories. Experiments can fail and become abandoned. However, teachers do not have the liberties scientists have. Even though IMSA teachers are highly qualified with Masters and Doctorate degrees, have teaching experience, and are respected as subject experts, their autonomy in curricular decisions and agency to make changes remains (and intensifies) under the scrutiny and approval of the hierarchy of power embodied in individuals in the school administration and school board. This power is also diffused (Foucault, 1977) to the public providing the gaze of approval or disapproval and needing justification of taxpayers' money in funding such a school. IMSA must succeed or demonstrate success in order to prove its worth for continual enormous state funding. Hence, IMSA as a laboratory should perhaps not be taken too literally as analogous to a scientific laboratory.

Vignette 2.

Daley did not see the correlation between AP scores or course grades and the quality of knowledge gained. Some students did not attain an A grade in chemistry because they expend effort on other subjects and doing other things like research or competitions. On the other hand, "there are other students that all they care about is getting an A, they just memorize how to do the problems and, and, so it's not necessarily; good learning is not necessarily reflected in the grade" (Daley, interview, March 6, 2009). However, there were some contradictions what Daley said about grades:

Although I'm talking about the difference between an A [Exceeds course requirements] and a B [Meets course requirements]. If someone is getting a C or D (raising his voice), they're not learning, like they should be. (...) Not AP score and not grades but I draw the line at IMSA below B, because, because let's face it. The kids are in high school; they want to go to college, you know so, part of, they're building a resume here. So if it's just a difference between an A and a B, I

don't care. I [Daley raises his voice] don't. Ah, now getting Cs [credit awarded, needs improvement] and Ds [Does not meet course requirements; no Academy credit awarded] which is failing at IMSA; D is a failing grade, that's a different story. So, I don't define it in terms of A versus B, or a 5 versus a 4 on AP. (Daley, interview, March 6, 2009)

Some contradictions were illuminated here Daley was held accountability to parents and school administrators. He felt the outcomes of inquiry learning were not measurable by conventional assessments such as AP or paper-and-pencil tests, quizzes, or examinations. However, the final scores, grades, and passing rates were concrete indicators of students' achievements used in college and scholarship applications. The school administrators and school board members also evaluated him based on these numbers and letter grades. Hence, Daley's vision of an inquiry curriculum was contested by the system of accountability creating internal dilemmas in his work.

Daley was also confronted externally in covert and overt ways. He believed most people were on board his curriculum change plans because it was beneficial for students; but not everyone shared the same view. Some students and parents thought IMSA teachers should prepare students for AP. He said,

AP Chemistry doesn't really fit with the philosophy of the academy very well. There are some academies out there that are better college preps schools. Their philosophies is, we're going to do whatever we can to get you as many fives on the AP. That's not our mission here. Now the parents and students might think it is. But it isn't. (Daley, interview, March 20, 2009)

Daley thought the school administrators trusted IMSA teachers to know and to do what was best for the students. He thought the school administrators were not looking at evaluative measures of the outcomes of curriculum change. He said,

Well I think they trust the teachers in that inherently the changes are good. I don't think they necessarily care to see measurables like higher AP scores. If that happens that will be great. If they go down I don't think I'm going to hear anything about it. If they stay the same it's going to be fine. I don't think they're

looking for measurables out of this. I mean often administrators are, but I think our administrators trust us. I think they understand that on our mission statements and on our SSLs, standards of significant learning, there is nothing in there about AP scores. They're not about teaching to a test, it's all about thinking, and integrating concepts and ideas. And, and working conceptually and thinking conceptually. And so I think they inherently understand that to make the course more lab driven and to put it upon the students as the learner to construct their own understanding of chemistry, I think inherently that they trust that makes a better class. So I don't think they are going to be looking at test scores or anything like that. I think they just think that it's a better class because we believe it's a better class. They, our administrators are very good about that. (Daley, interview, May 21, 2010)

Although the school administrators supported Daley's curriculum change plans, from a school administrator's standpoint, they expected Daley to have some evaluative measures to demonstrate the outcomes of change. This contradicted Daley's thinking that the school administrators did not look for "measurables". The principal said,

My biggest expectation is that they will evaluate how well it works. The problems when I run into with IMSA teachers is, you know, "How did it go?" "Oh well, I don't know. It seems that they did better". That's the problem. My problem, you know, we teach it in a revised way for two years and we see student learning gain on x, y, and z and drop down b and c. Let's make a reasoned decision whether it was worth it or what will change. (IMSA principal, interview, May 14, 2009)

The principal was disapproving of teachers who demonstrated lack of evaluative knowledge on students' learning outcomes. The President of IMSA also had similar expectations of Daley and the other advanced chemistry teachers. He said,

[I] think they really need to look before they start—how they are going to measure their success and how they are going to benchmark it. And that's one thing that's institutional; we really need to think of now much more, how we're doing in the programs. It's the 'how' we're going to measure and gauge success. I mean one of the reasons I'm behind today, I've got a call from the speaker's office, you know. How do you measure success in the field office? How did you measure the success of your E2K [Excellence 2000+, a student outreach program] you know. They want to see it makes a difference to students' learning. (IMSA President, interview, May 26, 2009)

From the administrative perspective, the principal argued that Daley would have sufficient curriculum time in the semester to continue his curriculum change after summer because they had relatively fewer teaching hours. Although Daley's colleagues at Lewey High School were envious, he argued he had spent more time grading and preparing laboratory activities—something which gifted student drove him to do for them.

Daley did not explain how his inquiry curriculum would be like. On the other hand, a key school board member understood that an inquiry curriculum would be one centered around questions that go for in-depth understanding rather than breadth. He said,

They're talking about inquiry and they are talking about deeper conceptual understanding of what's going on and those are all the terms that they tend to talk about. Then I think you can't talk about, we're going to do a little bit of this, and this, and this, and this, and this, and this. You have to take an area of the subject and if you're going to talk about inquiry, you need to ask the questions that are going to drive you in deeper, and deeper, and deeper. It only makes sense, and the students that they have are the caliber that should be able to do that. (School board member, interview, May 27, 2009)

This school board member was responsible of assessing the IMSA President's performance and himself was a principal of a large public school, pursuing his doctoral degree in education, taught AP biology and chemistry honors classes, and was a recipient of a statewide award for outstanding teachers. He understood the challenges in enacting an inquiry curriculum because the teachers in his school attempted to do the same. He said,

I think part of it is certainly as you go more into inquiry, you're not sure exactly where you're going to go with the students. It's a little more open-ended I think. Part of it will also be, if you're used to a curriculum that has a certain amount that needs to be get done, what happens if you don't it get done? So there's a comfort level that people would have to work with in order to gauge where they're going to be able to go. I think those are some of that. A lot of that will be the internal challenges, you know, some of the emotions that may go with certain curriculum

that they really love to teach, but might not get to, and what does that mean? And some of the unknown. If you start, if you kind of remove some of this, go to the, you know remove the breadth and go to the narrower focus, and in the end, does that prove to be something meaningful for students and are they able to still achieve at their levels or further? So there's a little bit of that too that they have to measure and figure out as they go along. (School board member, interview, May 27, 2009)

This school board member anticipated Daley might experience internal dilemmas in his decision-making. He saw inquiry as allowing more in-depth learning over breadth. He expected the inquiry curriculum to show an increase in students' performance.

Interpretive commentary for vignette 2. Daley met with internal and external dilemmas leading to tensions in his curriculum reform work particularly over the issues of accountability. He was equipped with knowledge, skills, and experience to rewrite the curriculum, had good quality and sufficient physical and human resources, and students who are academically talented, gifted and enthusiastic in science. In addition, he had the support from school leaders, and did not have to teach to statewide high-stakes tests. These conditions were more favorable as compared to most public schools. However, Daley was constrained by the limiting accountability systems narrowly based on numerical indicators derived from conventional testing. Daley did not express this constraint but had tacit knowledge of this unspoken 'rule' deeply ingrained through habituation. He also participated in reproducing the systems of accountability thoughtlessly or strategically.

Daley had possibly misinterpreted the school administrators and colleagues—they were playing the same game with different rules on the same court. He said the school administrators were supportive of teachers in risk-taking, but in effect the risk had to be highly calculated and within the structure of conventional accountability. Daley did not

think the school administrators were looking at evaluative outcomes, but the latter expected Daley and any teachers to provide concrete evidence of students' learning outcomes in their daily curriculum work and teaching. The principal found teachers who could not provide concrete evaluative accounts of students' learning outcomes problematic. His words embodied his authoritative voice and authority to demand teacher accountability.

Nonetheless, Daley was not alone in his "high-wire walk". In the next section, I describe other social agents who experienced dilemmas and tensions with the curriculum and in curriculum making.

High-Wire Walk By Other Social Agents

Daley's colleague, Choon, was not as confident about the school administrators' expectations. She expressed her confusion with the administrators' expectations and valuing of AP. She said at length,

I'm not clear on what the administration wants us to do. But what's really confusing is I know that teaching to AP chemistry is not always like helping them to grasp the concepts deeply. But I feel like they tend to, I mean almost all the students in our class are taking AP but we don't give them AP practices. We do as supplementary materials but it's not AP oriented class. Yet, we look at AP score. I mean if they have full grasp, understanding, they should do well, and that happens. But if we were to give them more practice, more like reinforcement and give them more time to work on AP type problems then they can do better. So I don't know, I think obviously with these kids, if we drill with AP they can score really well. But we don't, we choose not to, but then yet they'll look at AP score. You know what I mean? So I don't know, I think we really need to figure out what the goal is and I know that parents and students, they do want to do well on the AP so that they can save a lot of money in college when they get in there with credit. To me it's not clear like they keep telling me that they're trying to move away from AP but yet they look at AP scores time to time. Like administrators or the college CAC [College and Academic Counselors] counselors look at it and things like that, so I think there's a little disconnect there. (Choon, interview, May 7, 2010)

Choon felt there were contradictions in the school administrations' stance on AP. For example, IMSA did not offer AP, but the school administrators evaluated the AP scores. Choon also heard from students about the "latest trend" where CAC counselors advised students getting B grades to drop the class. Anecdotally, CAC counselors said to students, "[B]ecause in order to get into this college they [students] need this grade, so if you [student] can't get that grade in that course you might as well drop it" (Choon, interview, May 7, 2010). The CAC's counselors advice to students contradicted Choon's belief that students should struggle in their learning and work harder to improve. As such, Choon walked on her own high-wire in trying to make sense of these contradictions.

Students also walked on their own high-wires as they were confused with teachers' and administrators' expectations. In one pep-talk session which a student described as a "wake up call", Daley expressed disappointment with students' poor performance in advanced chemistry. He attributed it conclusively to students' low motivation. He brought in Bernice, the Director of Enrollment and Academic Services, to talk about the administrator's concerns about increasing number of students placed on academic probation. Students resisted some of the claims by expressing their opinions and views. I selected excerpts (presented in stanzas) of the dialogue during a chemistry period to illuminate the conflicts and contradictions between adults' and students' expectations contributing tensions to Daley's curriculum work.

Stanza 1

Bernice: Everything about the sophomore from May 15 to the end of the semester is going to be looked at under a microscope. Literally, such that we can say what we need to do to attend to your needs.

Daley: My job is to teach chemistry, but I'm stepping over. I think I know what it is. It's attitude. You struggle a lot more. I've never seen

anything like that in 16 years of teaching. The acid-base test. A full letter grade average lower.

Stanza 2

- Abha: I wasn't sure about something while studying for this quiz. I asked some people and they said it doesn't matter. I asked "Why not?" and they said, "It's really easy and besides you work with your partners". I don't want to rely on my partner even though it's a partner test.
- Masha: I think it's really hard to say that the students are mature enough to handle IMSA (...) and the tablets [computers] are only good if you're mature enough to use them (...). I guess my question is how did that reflect in our admission process?
- Bernice: The SAT-Math was looked at first because SAT-Math, as it has been shown through research, and I actually read about it this morning from somebody, had shown through research that SAT-Math is really a good predictor of talent and motivation of adolescents in math and science. And we are a math and science academy. So that's why we look at this first. It also relied on the professional judgment of the team. The GPA [grade point averages] was important to look at because it is a good predictor of motivation.
- Masha: I'm thankful that I was accepted even though my SAT scores were not high. But maturity is still important to look at.
- Bernice: Maturity will come through the GPA score, and so on.
- Daley: I don't think GPA is a measure of motivation for these guys. The reason is I think the school where you came from was too easy for you.
- Lily: Yes, I never had to work on projects over weekends.
- Laura: I could do my math work just before class and got an A. But at IMSA, I really had to work and be consistent.

Stanza 3

- Anissa: When I first came into the school in my sophomore year, he (a school administrator) said it was okay that we would be getting Bs. We need to be told the reality. Many IMSA teachers told the students that as well.

Masha: Students have the self-responsibility to ensure we did not settle for less.

Daley: The teachers and school administrator meant to not settle for a B when you could get an A.

Abha: My father told me the journey is important and when one had done everything right, then the outcome should reflect that.

Daley: I'm really scared about the AP chemistry scores. I am.

The three stanzas revealed different views about the admissions criteria for IMSA students, expectations, and outcomes of teaching and learning. In Stanza 1, Daley's said his job was not to provide academic counseling but he was crossing this professional sphere to address the problem of a whole lower letter grade in the recent test compared to previous years. He noticed the lack of students' motivation and attributed the poorer performance solely to students' attitudes. Bernice, however, stressed catering to students' needs illuminating different views of student self-accountability versus teacher accountability on learning. The "microscope" symbolized the scrutiny and surveillance the school administrators had over the teachers and students' performances.

In Stanza 2, Abha recalled her unpleasant account with students who abused the system promoting collaborative work—something Daley was constantly aware of and tried to limit in the revised curriculum. Masha contradicted Bernice's and Daley's views to 'blame' the problems on the school's one-tablet-per-student policy. According to her and some students in the class, some teachers were more lenient than others in monitoring the use of tablets in class and some students lacked self-discipline in the dormitories because they were not mature enough to stay in a boarding school. Bernice argued the test scores they looked at were reflective of maturity, motivation, and talent,

but Daley disagreed because the scores were not reflective of the type of schools they came from. Daley said the schools students came from were “too easy”, so they needed to put in more effort to bring up their standards at IMSA. Hence, one source of tension Daley faced was working with the vast variety of students with different abilities, backgrounds, and aptitude as the admissions criteria failed to effectively sieve out the ‘right kinds’ of students for IMSA.

Daley also faced tensions working with colleagues who expressed different expectations of students, causing the latter to work less than they should be able to achieve. Daley always set his expectations high for students to stretch their potential. But as shown in Stanza 3, some teachers and school administrators would tell students to work within their means and that a B grade was acceptable. He was not persuaded by his colleagues to lower his standards. He said,

I heard teachers saying that “Oh gosh, the students seem to be struggling more”. They would need to do something different. But, I can say this is the only mathematics and science academy. Supposed to be six hundred and thirty extremely bright gifted students in math and science. I don’t know why they’re not performing as well as my students did last year on the same teacher, or two years ago, I’m the same teacher, why aren’t they doing as well? You know I expect them to change. Maybe work harder. Motivate themselves more. (Daley, interview, March 6, 2009).

Finally, to end off the pep-talk on a serious note Daley spoke in a lower tone to project his deep worries about the coming AP examinations. He was still intrinsically concerned with the scores. This was a self-contradiction to what he said earlier, hence implying inner tension and struggle to balance on the high-wire.

Parents of IMSA students also experienced tensions in making decisions on school choices and their views were constitutive of the structure in which Daley’s agency was embedded. Parents bought into the narratives of IMSA as a prestigious institution

offering more challenging curriculum, highly qualified teachers, and better college opportunities for their children. However, they struggled with leaving their children at boarding school and were concerned about the disadvantage of non-AP preparations. Lily was a student from Daley's class in Spring 2009; her father was a physicist at Fermi National Laboratory and her mother was a teacher before she went into pharmaceutical sales. Lily's mother wanted her to become a doctor, but Lily did not like biology. Both parents were heavily invested in their daughter's education and overall well-being. Lily's mother would participate in the dormitory activities even though she managed to seek exemption for Lily to not live in the dormitory every weeknight. Lily's father would help her in mathematics and physics. Initially when Lily's mother heard IMSA was not offering AP, she was concerned:

I was feeling very insecure, well, because I know that, last year as a sophomore, I checked out the books she was learning, if the class had a book, and they were all college level books. So I couldn't understand why if IMSA made the effort to teach at the college level, why those concepts wouldn't be covered. So then I made the connection that probably if she has taken a college level chemistry course, she could also pass the AP with a little bit of self-study on the side. But ya, AP is a very huge thing outside in the public schools around us like in Naperville, Batavia and so on, that some of the kids can get enough credits to wipe-out their first year and all that's done in the school. But for us, we are able to do it but with a lot of effort, outside effort from the child and from the parents in making sure they have the books to study form. But ya, and I guess that would be a trade off, that that is something that IMSA doesn't offer and it is a little disappointing. (Lily's mother, interview, May 19, 2009).

Lily knew that her parents and everybody makes a "fairly big deal" (Lily, interview, May 12, 2009) out of AP. She bought some AP preparatory books, studied, and work on past year AP practice questions on her own. Lily's mother was not against the idea of AP and had little comments on the curriculum. As a parent, Lily's mother valued IMSA as a "top class" academy but she was also worried about Lily's overall well-being:

I believe that it is a top class education. I believe it will prepare her for college and for life. Sometimes I think the academic load is a little too much. The first year she came home and was you know, very extremely stressed because gifted children often are also perfectionist. And so if you give a perfectionist child a task, they will pull every hair in their heads and make sure that they're going to get an A. Of course here, not everybody gets an A, which is tough because then that translates to, you know now they are seeing their friends that have taken easy courses back at their old high schools getting straight A's and becoming valedictorians and that's about the only thing I think is unfair to the kids. That then they don't receive some titles that kids of lesser academics are receiving at their schools. (Lily's mother, interview, May 19, 2009)

She trusted the teachers to do their best for Lily but hoped the inquiry curriculum would not compromise students' results. She remembered how Lily had adverse reactions to a class which did not test to the content:

I know she was having a little tough time with physiology because at the beginning she took her first test and almost flunked because she said, we don't know it's true or not, that the teacher didn't teach what was taught in the class or in the book. So that really threw her off. And I said you'll meet teachers like that in your educational lifetime. So maybe it's a preparation thing, you know, heads up. But that really dissuaded her from that class for a while. But then she got back into things in that class and now is doing just fine. But it prompted her to take that class pass/fail, because she was terrified that she won't be able to pick up all the concepts. But that's the kind of fear that kids have in them. (Lily's mother, interview, May 19, 2009)

Hence, Lily's mother hoped students to be tested on the information taught. She wanted some "check and balance" (Lily's mother, interview, May 19, 2009) between inquiry teaching and content teaching.

When Daley presented his curriculum reform plans at the NCSSSMST conference in Spring 2009, it was attended by school administrators, teachers, and educators from other specialized schools. Daley's presentation and curriculum reform ideas attracted a lot of attention and feedback from school administrators and teachers who thought he was "brave" but his plans were unfeasible for realistic reasons. He recalled what happened after his presentation:

Their [Torrey High School—a top US high school] principal came up to me in my session that I presented about the changes and said you can never do that in our school. He said it was a great idea, but we're all about AP scores. You know, we can never let it happen. So there're schools that are dead set against it. I think there're schools that are moving towards this kind of learning. (Daley, interview, March 20, 2009)

Many high status schools were abandoning AP because it lacked the rigor in differentiating and challenging the academically more capable students (Schneider, 2009). However, the responses and reactions Daley received at the conference showed that AP continued to be highly valued and 'indispensable' for some schools. Daley recalled some people in the audience said to him AP was a "big thing". As such, schools could not afford to abandon the program. For example, Torrey's High School principal's reacted negatively to Daley's plan. Daley said,

Because Torrey [High School], first of all, is very ethnically not diverse. Very homogenous population. Very wealthy groups of students. I don't know the percent of Caucasian, but way high. Very rich area, not like IMSA that serves the entire state. I believe. You need to check on that. but I believe it serves an area, a region, and and and it's more of a school for wealthy kids than we are. So you have this very homogeneous population. It fulfills more, I think what's a typically, and I think they call themselves as, it's more a typical college prep[aratory school], that the idea is to get the students AP scores. The other thing is, there're a lot of scholarships. We don't have grade point average at IMSA. We don't count their GPA. A lot of academies still do and they weight honors courses, and honors courses have the name AP in them. And when the kids apply for scholarships, Cope scholarship for example, they look at the number of AP classes they took. And so there is a practical reason to have AP in the name of the course. For weighting, for recognition and scholarships. (Daley, interview, March 20, 2009)

The IMSA principal, who said he was well acquainted with Torrey's High School principal, reasoned that the latter was "definitely speaking from the point of what the parents in that area expect" (IMSA principal, interview, May 14, 2009). The principal thought this problem was more peculiar to Torrey High School than it was to IMSA because the "clientele" the two schools served were different. This was a good example

where “Schools and their curricular and teaching policies and practices *are* increasingly being pressured to conform to economic needs as defined by the powerful” (Apple, 1986, p. 17).

Summary. I have discussed inherent contradictions and conflicts between Daley’s ideas and assumptions with those of the school administrators which could lead to tensions. Daley did not articulate any knowledge of his inquiry-based curriculum reform being shaped by dominant views or ideologies. A school administrator felt Daley did not seem to understand the broad implications and significance of this work. Hence, Daley did not seem to be critically aware of how his teacher agency was circumscribed by the sociocultural and sociopolitical factors and forces of the context. This reflects the idea that domination is a subjective experience internalized and sedimented to repress and create obstacles to self-knowledge and hence social and self-emancipation (Freire, 1970). To be emancipated from these constraints, Daley must first be clear about the forms of domination, the source and nature of its origins and location, and the problems posed to people who experienced it.

Curriculum Planning and Design

Daley, Reina, Alisa, and Choon had four meetings in Summer 2009 to deliberate over the curriculum changes the following academic year. They spent a total of 180 hours of paid summer curriculum time to do their work. The teachers made a list of items they wanted to change and the desired outcomes, selected readings and book problems, planned out the calendar of lessons for every unit, wrote appropriate assessments including summative and formative ones, and homework checks. Daley described what he and his colleagues did,

We tried in our curriculum work to cut down some of that [content], rewrite some labs, completely do away with some labs and bring in more labs. Increase the time that students are working in class, less teacher talk, more student centered work. The overall goal is to make the class more engaging for the students and reflect better the IMSA SSLs [Standard of Significant Learning] and mission statement. (Daley, interview, September 10, 2009)

The teachers made instrumental, epistemological, and practical value-based considerations in the curriculum meetings to inform curricular and pedagogical decisions based on individual and collective consensus, teachers' experience, and knowledge. At the last curriculum meeting, the teachers volunteered to take up units they would be placed in charge of revising. Daley said, "I think all the teachers understood what we were trying to do and so even though different teachers worked on different units we're kind of seeing the same ideas" (Daley, interview, September 10, 2009). Subsequently, they communicated by electronic mail and deposited electronic copies of their work on the shared electronic folder accessible to teachers. I will now describe and discuss some changes in detail.

Daley found the unrevised curriculum covered too much content such that there was insufficient time for students to work on laboratory activities. They reduced the number of learning objectives from 84 to 63, of which 44 were kept, 15 were modified (two objectives combined with another objective), 25 were removed, and six new objectives added. Some learning objectives were removed as they were related to content knowledge Daley and the teachers felt students were capable of self or peer-learning. A major change in the curriculum was the increase in assessment weight from 40 percent to 70 percent—a decision Daley said was made by "four PhDs" (Daley, lesson observation, September 10, 2009). Daley explained this change:

We changed the grade weighting in the class from only 40 percent test and quizzes to 70 percent test and quizzes just because I felt students were not held accountable for their learning. I thought that they could do lab reports with the assistance of; you know they can collaborate outside of class. I'm not saying cheat. I'm saying collaborate legitimately. You know, they produce beautiful lab reports and produce beautiful homework but if they're not internalizing and understanding the material, they can't produce on an exam. And I don't think they've shown me they know very much. So we all agree, change grade weighting. So the grade weighting is much more emphasis on tests and quizzes now. On the other hand, we're giving more practice quizzes ahead of time for the real one. We're doing a better job I think at getting ready. So even though the grade weighting is changed I think they're held more accountable. (Daley, interview, September 10, 2009)

Daley and the teachers placed great emphasis on student individual accountability because they noticed many students could fail badly in the final examination and still get an A or B overall grade based on their graded assignments and laboratory reports. By increasing assessment scores, the grades would be better indicators of students' own knowledge and/or understanding. However, this contrasted with IMSA's policy on encouraging student collaboration—the reason why students' GPA were not counted.

Daley wanted students to be able to integrate their knowledge better. He said he and his colleagues talked about making a spiral curriculum:

It's a little more of that spiraling idea of education that that is kind of a hot commodity right now, a hot idea. You know we, we learned, we dabble with something, we learn but then we move on but then we come back to it. And then we learn it in new context and then we are constantly revisiting ideas and then I think you see that as a theme throughout our units. Not only within units but tying the units together. (Daley, interview, September 10, 2009)

Daley and the teachers had this idea of learning which involved constant revisitation to reinforce and further develop existing knowledge students acquired within units in this course. To ensure better flow of ideas and conceptual development, they also changed the sequence in which the topics were taught.

Daley restructured his lesson period to balance content teaching and laboratory learning. He described what he did in the first few classes of the revised curriculum:

They are getting used to coming in and working. You know they don't listen to us talk. They come in and they get to work and they, and the interesting thing is that when the teachers do say, I want to talk to you for fifteen minutes, they pay attention. You know what I did the other day, we were building molecules with kids and looking at them. It's a whole lab on VSEPR [Valence Shell Electron Pair Repulsion]. You know, hybridization and polarity, geometry, orientation. Bond angles. They came in they get their kits out they started working and I let them work for fifteen minutes. I interrupted them and they came up and we talked about polarity for just a few minutes. And I said okay we'll go back and work some more and they go back for another maybe half an hours worth of work and I said okay come back up front and we talked about hybridization for another 20 minutes. And so we're breaking up lessons into little bits of time while they're working in between. (Daley, interview, September 10, 2009)

Daley rationalized the twice-weekly 95-minute period made it an appropriate laboratory session. He could not make changes to the school timetable so he adjusted his lesson time to include several short activities. Daley tried to personalize learning—an advocacy of the principal—by adding pre-laboratory questions and post-laboratory questions.

Students who came to class prepared or were more on-task in class would complete the pre-laboratory questions faster, started the laboratory activity earlier, and had more time to work on the post-laboratory questions. He wanted to use this method to promote student accountability and self-motivation in learning.

Interpretive commentary. 'Hard' changes were made to the learning objectives, assessment weight, curriculum materials, laboratory activities, teaching, and nature of the curriculum time to achieve 'soft' or intrinsic outcomes or changes in students. Daley could be described as engaging with the three intellectual virtues—episteme, phronesis, and techne—(cited in Flyvbjerg, 1991)—in his curriculum work and teaching.

Epistemological considerations include asking how is knowledge produced and what is

considered as legitimate knowledge. In this case, Daley believed knowledge must be constructed by students as they drew on their prior knowledge and experience across discipline and within topics in chemistry for real life application. Daley's role as a teacher was to help students make these connections and applications; this he was able to do with his background in biochemistry. Phronesis, which is dependent on experience, emphasizes practical knowledge that is context-dependent, and practical ethics involves deliberation over values with praxis. Daley's idea of student accountability was related to this value-based deliberation. He strongly believed students should learn to collaborate intellectually but produced work that reflected their own understanding. He recognized the flaw or loophole in the system which allowed students to inflate their grades. He adjusted the assessment weight, devoted more time for in-class work, and created varied versions of quizzes and examinations for different sessions so that students would be deterred from cheating. He also wanted students to develop technical skills by being able to work efficiently in the laboratory, collaborate with peers, and manage test questions. In thinking about and with resources and factors, Daley actually applied his technical knowledge and skills in creating laboratories, designing, planning, enacting, and evaluating the curriculum based on his prior knowledge, experience, and skills in teaching, working with colleagues, and students. This technical or instrumental rationality was described by Foucault (1984) as "a practical rationality governed by a conscious goal". In the next section, I present three sets of narratives to illustrate the lessons before and after curriculum change.

The Unrevised Curriculum

Vignette 3—‘Blue bottle’ reaction mechanism [February 27, 2009].

After introducing the concept of reaction mechanism using a PowerPoint, Daley told the students they would do a mini-laboratory activity today. The students crowded in front of the demonstration bench. Daley instructed students to pick up a conical flask each and work in their usual laboratory groups. He said that this was one of the simplest laboratory activities for the whole year, but also the “hardest to explain”. He instructed the students to place their thumb over the stopper, shake the flask, rest it on the table, and observe changes. The process was repeated.

Laura: It’s [color] gross!

Daley: We’re going to play a little game of figuring out the reaction mechanism. It is extremely hard to do, but I will provide hints and tell you what are the materials in the bottle. What are the observables?

Rebecca: The reaction is reversible.

Daley: I will tell you a secret. When I prepared the sample, it was clear, not yellow.

Daley walked to the whiteboard and wrote: G, OH⁻, A, X

G = ____; OH⁻ = OH⁻ !!!! ; A = ____; X = ____

Daley: G is glucose and it probably broke down overnight and turned yellow. What is the shaking doing?

Lily: To let the air in.

Edward: Bubbles.

Daley: You can take the cap off and see if the change is faster or slower. The mixture has excess OH⁻, so what is the solution?

Masha: It’s a base.

Daley: So make sure you wash if you're in contact with the base even if it is only one molar. In the previous class, one student forgot to stopper the flask and the solution showered and splattered all over, including the goggles. What do you think the shaking is doing?

Rebecca: It is forcing collisions.

Daley: Not really...if it was to force collisions, then a higher temperature would also cause the color change. Let's test your reasoning by using the hot plate to heat up the mixture. (Daley returns with a tub of ice.) Who wants to chill out?

Lily tried heating the flask on a hot plate, while Santos placed his flask in the tub of ice.

Sally, Rebecca, and Isabel asked Daley for help because their stopper was trapped in the neck of the flask. Daley identified this to be an interesting phenomenon that was related to the experiment. He explained to the three girls what happened. After that, he had Sally explain the ideas to the rest of the students. In her own words, Sally explained that when the flask was shaken, the oxygen was taken up by the solution. This resulted in a lower pressure in the flask and hence, the stopper was 'sucked in'. Daley added that once the oxygen went into the solution, it was not released back into the air. At this juncture, he asked what is A? The students responded, "oxygen".

Daley revealed that the reaction underwent a four-step mechanism and the color change did not occur in the first step. The students were appalled when they heard that there were four steps in the mechanism, laughing at their own plight. After a while, Daley revealed the identity of X as methylene blue. He wrote on the whiteboard:

X = methylene blue (reduced-clear)
= " (oxidized-blue)

He wrote the first step of the mechanism on the whiteboard: $G + OH^- \leftrightarrow G^- + H_2O$. He walked around and asked if the ice did anything to the color change. Santos said the cooling did not cause any color change. Daley asked what happened on heating and Lily reported it did not cause a color change except, but she had to shake the flask harder to observe a color change.

The students continued to figure out the subsequent steps in the mechanism. Pairs of students started congregating into a larger group and students talked about their ideas. Daley walked over to a group and heard Katherine's correct suggestion for the second step. He invited her write it on the whiteboard. She wrote: $A(g) \rightarrow A(aq)$

At this time, Daley decided to do a side experiment. He mixed some chemicals in a flat bottom flask and walked away. Lily asked him what he was doing. He said that he was testing his own hypotheses and would divulge it in the next lesson. Mack offered his suggestion for the third step to Daley. Daley invited Mack to write his answer to the third step: $A(aq) + X \rightarrow B$. Daley asked, "What has to be in the fourth step?" He continued, "B has to go back to X. What must be present to go blue?" He turned around and suddenly noticed the blue solution in his side experiment had turned clear. He became very excited and diverted his attention to his side experiment. He told the students he did not add glucose earlier and so the color did not go away. But when he added in the glucose, walked away, and turned around, he suddenly saw it turned clear. He was very intrigued and wanted the students to think about it. Soon after, Lily figured out the fourth step and Daley invited her to write it on the whiteboard. She wrote: $B + G^- \rightarrow X + \text{products}$. The 'puzzle' was solved.

Before the end of class, Daley shared he had thought of a better way to do this activity next year. He asked the students for feedback on how they would prefer the activity to be conducted differently. Some students said that they would prefer to do the chemical mixing themselves. Daley suggested he might have one group of students work without glucose and the other group work with glucose.

Interpretive commentary of vignette 3. Daley conducted this inquiry laboratory in Spring 2009, prior to curriculum change. Daley liked this activity because it was open-ended, but another advanced chemistry teacher was uncomfortable with the inconclusive answers and decided not to conduct the activity in her two classes. Daley felt he could lead students to suggest possible answers coherent with the observed phenomenon. This approach also taught students the idea that reaction mechanisms could not be proven and many answers were possible. Although Daley sounded disappointed that his colleague did not want to conduct the activity, he respected her decision and made it an optional ungraded laboratory activity.

Daley felt these kinds of ‘inquiry’ activities could make students think as they performed experiments. This approach was different from giving a lecture on reaction mechanisms. This lesson resembled guided-inquiry, as he led students to deduce the mechanism by disclosing identities of the components at appropriate junctures while monitoring interests and progress.

An idea illuminated in this activity was that inquiry-based laboratories must be accompanied by some degree of decentralization of teacher control. Daley experienced tensions in deciding how much authoritative control to give up in the inquiry-based curriculum and this shaped the form of inquiry he adopted. He “relinquished” some of his

authoritative control and voice to students inviting them to offer suggestions, make deductions, and test their ideas while he facilitated the process by dispensing clues at appropriate junctures and providing materials. He asked questions, encouraged students to ask questions and give suggestions as well, using them as initiators to press on the inquiry. For example, he did not dismiss Rebecca's suggestion of "collisions", but challenged her thoughts by having students test this idea using ice and hot plate. He provided the opportunity for students to make connections to a concept they had discussed earlier: *higher temperature leads to higher frequency of effective collisions and hence faster rate of reaction*. He was pleased the students derived the second and third equations through their own thinking and using the hints he provided.

There was also an interesting change in the class structure and dynamics as students encountered more uncertainties. Pairs of students congregated to form larger groups hoping to brainstorm more ideas. Daley did not restrict the movements, but allowed students to identify 'free' space, reorganize their groups, and interact freely. According to Daley, this inquiry-based activity was an example of authentic scientific inquiry. The flexible change in social dynamics paralleled the environment of real scientific research as researchers often move within and outside of their research laboratories to form collaborations, share equipment and other resources, brainstorm for new ideas, and problem-solve especially when the task becomes too daunting for individuals, small groups of people, or separate laboratories to handle.

Daley's inquisitiveness and quick thinking prompted him to do a side experiment to verify his own predictions and that action triggered some students' interests. Although this was not part of his planned lesson, he demonstrated positive attributes and skills his

students could model in doing authentic scientific work. Daley had engaged some reflexive practice as he invited students to provide immediate feedback to improvise the activity for next year's curriculum. This input could add to his personal practical knowledge (Connelly and Clandinin, 1988) and inform his inquiry-based curriculum design. Daley found this experiment engaging for students and included it in the schedule of the revised curriculum. However, they did not get to enact it because too much time was spent on the introductory lessons of the unit. I will now provide the vignette of a new laboratory activity introduced by Alisa into the revised gas law unit. She had used this activity in her community college class and IMSA outreach summer camps and after-school programs for children.

The Revised Curriculum

Vignette 4—Air bag experiment [October 19, 2009].

Students were arranged in groups of four to work on the “Air Bag Laboratory”. Daley began the lesson with brief instructions on the activity. The students were told to read the laboratory worksheet before coming to class, so Daley expected them to know what the experiment was about and what they had to accomplish. In this experiment, the students had to integrate and apply concepts of double-displacement reaction, stoichiometry, and gas law to complete an investigative task. The goal of the experiment was stated in their handout:

Your goal is to determine the exact amounts of two reagents, solid baking soda (sodium hydrogencarbonate, NaHCO_3) and 0.8 moles per liter of sulphuric acid (H_2SO_4) to combine in a resealable plastic storage bag, such that the carbon dioxide gas produced will inflate the resealable bag until it becomes taut. However, the resealable bag must not explode or leak!

To help the students start their investigation, Daley prompted them to suggest ways to determine the volume of the resealable plastic bag provided. A few students suggested filling the resealable bag with water then measure the volume of water it contained using a measuring cylinder. The rest of the students agreed that it was a feasible idea. They worked in their usual laboratory team of four to carry out this investigation at the laboratory benches. The students collected measuring cylinders and resealable bags from the common laboratory bench packed with different apparatus and chemicals. Daley walked around the laboratory benches to observe the students as they carried out their investigation. After the students had determined the volume of the resealable bag, they returned to their seats at their desks.

After sharing their findings, Daley told the students that they had to think and discuss with their team members how they would inflate the resealable bag completely using the chemical reagents given. He did not provide further instructions, prompts, or hints, but gave them the green light to gather in their groups to discuss and consult with their team members. The students discussed which gas law equation to use, what values they needed to do the calculations, and how they would perform the actual experiment. Ryan and Minho were first to take the pressure and temperature readings on the barometer and wall thermometer. Subsequently, more students from other groups followed.

Every group of students applied the ideal gas law $PV = nRT$ (P is pressure of the gas approximated to be the atmospheric pressure, V is the volume of the resealable bag, n is the number of moles of the gas produced from the reaction, R is a gas constant known to be $0.0821 \text{ LatmK}^{-1}\text{mol}^{-1}$, and T is the temperature of the gas approximated to be the

room temperature) to calculate the number of moles of carbon dioxide (n) required to completely fill the resealable bag. Minho substituted the values of the atmospheric pressure and temperature into the ideal gas equation to calculate the volume of gas (also the volume of the resealable bag) required to inflate the resealable bag. Then he wrote the balanced chemical equation to represent the reaction between baking soda and acid to determine the mass of these chemicals to combine to obtain the required volume of carbon dioxide. Not all students participated in the activity in the same way. Some of them worked enthusiastically on the calculations, while others stood next to their team members to provide suggestions or observed.

After approximately 10 minutes of group discussion, Daley asked the students if they were ready to begin their experiment. He told the students that this was a competition and the group that was able to inflate the resealable bag most without exploding would gain an additional point counted towards their assessment grade. He reminded the students to think about how they would combine the reactants without the gas escaping.

Adeline, an outspoken and enthusiastic student, asked Daley if they could carry out some experimental trials to make sure that their calculations worked. Daley asked if other students would also like to carry out trials and some students concurred. When Daley acceded Adeline's request, she and her team member, Nyah, immediately jumped out of their seats and walked hurriedly to a laboratory bench. Two other team members, Adria and Kovan, quickly stood up from their seats, and followed along. Minho, a Korean male student who often took the lead in laboratory activities, saw Adeline's group starting on the trials. He rallied his peers, Ryan and Karter, to do a trial too. Other group

of students continued to work on their calculations. After another five minutes, all the groups began their trials to test if their calculations worked.

Daley was working on his laptop. After he saw all the students had started on the trials, he left his teacher's bench and walked over to observe the students carrying out their investigations. He stopped by Adeline's bench and leaned against the opposite side of the laboratory bench to observe her, Nyah, Adria, and Kovan carrying out the trials.

Adeline used the weighing pan and weighing boat to weigh out the amount of baking soda they calculated. Nyah and Adria recorded the actual mass of baking soda weighed out. Then, Kovan measured out the volume of sulphuric acid using a 100-ml measuring cylinder. He used the dropper to add the sulphuric acid into the measuring cylinder. Adeline told him to hurry up the process and suggested pouring from the bottle instead then use the dropper only closer to the mark. Kovan followed her instructions. After Kovan had measured the required volume of acid, Adeline told Kovan to pour it to the resealable bag. She told Kovan to twist the resealable bag to remove the air. I was standing next to Daley and he commented to me, "Look at how they are working together! Isn't that fascinating teamwork?" I nodded, expressing that I agreed.

Adeline suddenly thought of an idea and excitedly asked Daley, "Dr Daley, Dr Daley, can I suck the air out?" Daley thought he heard her wrongly and Adeline repeated her question. Daley raised his eyebrows and voice and answered, "No!" He lowered his voice and explained to her, "You may suck in acid vapor. Just use you hand to squeeze the air out." Adeline acknowledged that possibility and safety hazard and responded, "Oh! That's right. Okay!" Kovan held the resealable bag while Adeline poured the baking soda through a small opening of the twisted resealable bag. Adeline sealed it up

after the baking soda was added. Together, Kovan and Adeline held up the resealable bag and shook the mixture. The baking soda and acid sizzled very quickly upon contact. Adeline, Nyah, Adria, and Kovan gasped with excitement when they saw the almost instantaneous reaction. A colorless gas caused the resealable bag to become inflated in less than 20 seconds and a colorless liquid remained in the resealable bag after the mixture stopped sizzling. But they were disappointed when the sizzling stopped—indicating that the reaction had ended—even before the resealable bag was completely inflated. Adria poked at the resealable bag and said, “It’s so sad”.

Adeline suggested adding more baking soda and acid in the next trial. Nyah asked how much she wanted to add and Adeline answered, “Arbitrarily more.” Nyah grinned. In the second trial, Adeline decided to add about 0.5 grams more of baking soda and five millimeters more of acid. Kovan and her repeated the procedures, but again the gas produced was not enough to cause the resealable bag to become taut. They used even more chemicals in their third trial and successfully inflated the resealable bag until it became taut.

Daley walked around to observe other groups of students after Adeline’s first trial. He smiled as he saw more groups being successful in their attempts. After 15 minutes, each group had attempted at least one trial. Daley wanted the students to begin their actual demonstration. He told the students to gather at the middle laboratory bench in the front row to watch the first group of students demonstrate how they inflated the resealable bag. Alister, Idelia, Vati, and Ling had already weighed out the baking soda and measured out the volume of acid. Daley did not ask how much baking soda or sulphuric acid they measured or how they determined the amounts to add. They

demonstrated how they add one chemical, remove the air, add another chemical and kept them separate, mixed the chemicals, and inflated the resealable bag. Although they inflated the resealable bag, it was not completely taut. It was slightly dented when Daley pressed on the resealable bag. Subsequently, each group of students took turns to demonstrate how they worked together to combine the chemicals and inflate the resealable bag. The students clapped, screamed, and cheered when the resealable bags became taut and almost burst.

Karter and Minhó added more baking soda and sulphuric acid than other groups such that the gas produced almost exploded the resealable bag. Earlier, Minhó figured out that the acid was colorless so if they added a large amount of baking soda and excess acid, nobody could tell that excess acid remained because it looked like water, which was the end product. Minhó thought it would be exciting to see the resealable bag explode. When the resealable bag became taut, Karter threw it into the basin because Minhó kept shouting, "It's going to explode! It's going to explode! Throw it into the sink!" Kaden dropped the resealable bag into the sink. Daley placed the wooden block over the basin in case the chemicals splashed out. The students who were standing near the basin took several steps back. After about a minute, Daley removed the wooden block, peered over the basin, and stretched his hands to hold up the resealable bag. Only a colorless liquid remained and the resealable bag was leaking. Minhó said it was a safety feature of resealable plastic bags. Daley and the other students were amused by Minhó's funny but quick-witted comment and laughed. Other resealable bags also leaked when it was inflated until taut. At the end of the student demonstrations, three groups successfully inflated the resealable bag and Daley decided to award bonus credit all three groups.

Interpretive commentary of vignette 4. This laboratory activity was accompanied by a handout with instructions on the goal of the experiment, pre-laboratory calculations similar to the ones students had to do for the actual laboratory experiment, and post-laboratory questions. When students worked, Daley mainly walked around the laboratory to watch them perform the experiments or helped them with supplies. His role was more of a passive observer and supervisor; not mentor or facilitator of inquiry. When the activities are proceeding smoothly, he would return to his teachers' bench to do his work and observed from his seat. If students had any questions, they would approach him at his bench to seek clarifications, verifications, or confirmations. In transiting from the front of the class where student's desks symbolized desk work, to the back of the class with laboratory benches, a shift from teacher to student-centered learning followed. Further, the few available bench stools symbolized space for students' hands-on work, movement, and teamwork as opposed to individual deskwork. Daley's role also shifted from teacher to become an observer, troubleshooter, safety officer, and provider of laboratory supplies.

The goal of the experiment was clearly specified and students knew what they were tasked to do with the given materials. The procedures were not provided, but information such as the size of the plastic bag, concentration of the acid, and formula for the chemicals were provided. The criteria were that there should be no excess chemical remaining and the plastic bag must become taut without exploding. Using the theoretical amounts of chemicals, students learned that the gas produced was sufficient to inflate the plastic bag but not caused it to become taut. All the groups arbitrarily increased the amounts of chemicals rather than recalculating the exact amounts of chemicals to

combine in subsequent trials. That was because they realized the excess acid and the product (water) were both colorless liquids and hence not easily differentiated by direct observations.

This activity and questions in the pre-laboratory and post-laboratory helped students to integrate concepts from various units. In the pre-laboratory section, students had to combine concepts from chemical reactions, chemical equations, stoichiometry, and gas laws to determine the theoretical amounts of acid and base to combine. The post-laboratory question included the concept of density, which the students learned in their foundational course. This achieved Daley's goal to have students make connections. In the post-laboratory section, students had to explain the difference in theoretical and actual amounts of gas needed to make the plastic bag taut. Nityan correctly suggested that the elasticity of the plastic bag could play a part in this discrepancy.

Before and After Curriculum Change

In the unrevised curriculum, Daley taught buffer solutions using an "interactive" demonstration. Students were given a worksheet with a list of instructions to make a buffer. They sat at their desk while reading out each step to Daley as he performed the work. In the revised curriculum, this activity was replaced and students had to make their own buffer solutions. Vignette 5 and 6 are narratives of both lessons before and after curriculum change engaging students in contrasting ways.

Vignette 5—The unrevised curriculum on buffers [March 24, 2009].

In the first part of the buffer activity, Daley had two students, Rebecca and Anissa take the lead in adding different indicators to different concentrations of weak and strong acids and bases. They would dictate the colors they observed and the rest of the students

recorded it. This color change in different pH was used as a reference for the interactive demonstration later. After students completed this activity, Daley told them he would begin the “interactive demo”, where the students had to participate by telling him what to do. The instructions provided on the worksheet is shown below:

Interactive Demo: Making a buffer

Let's work together to complete this activity. Teachers will ask for assistance with certain steps. Calculations will be completed as we work together (use your notebook).

1. Prepare a solution by dissolving of 26 ml of 6 M $\text{HC}_2\text{H}_3\text{O}_2$ in 800 ml solution. What is the $[\text{HC}_2\text{H}_3\text{O}_2]$ in this solution?
2. Divide into two 400 ml portions. Labeled A and B.
3. Prepare the buffer: Add methyl orange to A followed by the addition of 6.6 g of $\text{NaC}_2\text{H}_3\text{O}_2$. Note color change. Set B aside.
4. How many moles of the base were added? What is the $[\text{NaC}_2\text{H}_3\text{O}_2]$?
5. Calculate the pH of the $\text{HC}_2\text{H}_3\text{O}_2$ and the $\text{HC}_2\text{H}_3\text{O}_2/\text{NaC}_2\text{H}_3\text{O}_2$ solutions. Do the colors of the indicators confirm your pH calculations?
6. Prepare an unbuffered reference solution: Take 800 ml of 1×10^{-5} M HCl solution and divide in two 400 ml portions (labeled C and D). Add methyl orange to C and set D aside.
7. Demonstrate buffer capacity: gradually add 5 ml of 6 M HCl to A (note any color change?) and 1 drop to C (note any color change?).
8. What is happening in container A? In C? Calculate the final pH in each solution (assume 1 drop = 0.05 ml).
9. Let's now use solutions B and D. Add methyl red to B followed by the addition of 6.6 g of $\text{NaC}_2\text{H}_3\text{O}_2$. Note color change. Add alizarin yellow to D. Note color of solution.
10. Demonstrate buffer capacity: gradually add 5 ml 6 M NaOH to B (note any color change?) and 1 drop to D (note any color change?).

11. What is happening in container B? In D? Calculate the final pH each solution. (Assume 1 drop = 0.05 ml)

The students referred to the list of steps on handout and read out step 1: "Prepare a solution by dissolving 26 ml of 6 M HC₂H₃O₂ in 800 ml solution." Daley asked if he should add the acid to the water or vice versa. He answered it is not critical here because it is a weak acid. He transferred 6 M acetic acid into a small measuring cylinder and filled a larger measuring cylinder with about 600 ml of deionized water. Lily asked why he does not use 800 ml of water. He explained if he added the 26 ml to the 800 ml water, the final volume would not be 800 ml. He commented the acid was really concentrated and the smell was very strong. He poured the acid into the deionized water. He added some deionized water into the smaller measuring and told the students he was ensuring "quantitative transfer" of the acid. He repeated it a second time. He stirred the mixture and asked if the beakers provided accurate measurements. The students said no and he added that it was good enough for this experiment. He poured 400 ml of the dilute acid into two beakers. He said that the students were 'tricky' in not reading out the question on calculation so that they can skip the math. He showed them the working:

$$26 \text{ ml} \times 6.0\text{M} / 800 \text{ ml} = 0.195 = 0.2 \text{ M}$$

He went on to the next step to add methyl orange to A. He described the color as "salmon". Reina walked in from the back of the class, saw him adding too little, walks up to his bench and pour in more methyl orange. The color turned brightly orange.

Daley added acetate powder to the solution. He asked what kind of solution he had created with acetate and acetic acid. When the students did not respond, he asked for the name of this demonstration. The students said, "buffer". He acknowledged and asked, "Why is the mixture a buffer?" Daley told them it was because it contained a weak acid

and conjugate base. He moved on to the question on the concentration of sodium acetate on number 4. He showed the working:

$$6.6 \text{ g NaC}_2\text{H}_3\text{O}_3 / 82.04 \text{ g/mol} = 0.080 \text{ mol (80 mmol)}$$

He gave the molar mass of sodium acetate. He asked the students to convert the .080 mol to millimoles units which they would use later. He wrote:

$$[\text{NaC}_2\text{H}_3\text{O}_2] = 0.080 / 0.400 \text{ L} = 0.20 \text{ M}$$

He reminded the students that sodium acetate was an ionic compound and asked what happened to it in water. The students said that it would dissolve. Daley used “dissociate” as a more accurate term. He told them that there are two ways to make a buffer. One way was to pour some acid and base and mix them together. The other way was to use titration to create a buffer. Rebecca asked Daley, “What is the purpose of a buffer?” He wrote on the whiteboard: “What is a buffer? A solution that resists a pH change.” He added: “What is in a buffer? A weak acid and its conjugate base.” Rebecca said that she knew what was a buffer but did not understand why we need it. He asked what was the pH of blood. A student said, “7.14”. He said that if the pH of blood goes too acidic or basic, we would die. He said that there is a buffer system in our body and wrote the equation: $\text{HCO}_3(\text{aq}) \leftrightarrow \text{H}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$. He elaborated there is carbonic acid in our body because of dissolved carbon dioxide. The carbonic acid would ionize to form H^+ and HCO_3^- .

Daley: What is present to make it a buffer? Carbonic acid is a weak acid and HCO_3^- is a conjugate base. How does it work? If you add acid, you try to change pH by adding acid, what will absorb the acid?

Students: Base.

Daley: Base. If you add hydroxide, what will react with the hydroxide?

Students: Acid.

Daley: There will always be something in there that will react with the acid or base. The pH will change some, but not as much. By the way, has anyone seen someone hyperventilating?

Students: Yea.

Daley: What do you do when you hyperventilate? Do you breathe in or back?

Students: Back.

Daley: Why do you breathe back because if you blow carbon dioxide too quickly, the concentration of carbonic acid will decrease quickly and the pH will change quickly. You will die. This is what we call alkalosis. It is good to ask.

Daley continued with Step 5 which asked students to calculate the pH of acetic acid and the buffer solution. He showed them the working, using the results from the 'ICE' (initial, change, equilibrium amounts) table:

$$pH \text{ acetic: } x^2/0.20-x = 1.8 \times 10^{-5}$$

$$x = [H^+] = 0.0019$$

$$pH = 2.72$$

Daley asked what equation they will use for the buffer. Anissa said, "HH" to mean Henderson-Hasselblach equation.

$$pH \text{ Buffer: } pH = pK_a + \log [B]/[A]$$

He asked what was the concentration of the base and the acid in the buffer. The students said that they were equal. He wrote $pH = pKa = 4.74$.

He moved onto step 6 to pour the prepared HCl (hydrochloric acid) solution into two beakers and added methyl orange. He reminded students that A is a buffer and C was not a buffer and wrote it on the whiteboard. He moved onto step 7 to add 5 ml of 6 M

HCl to beaker A (containing the acetate/acetic acid buffer) very quickly and the color did not change much. He added one drop of HCl to beaker C containing HCl and the color changes from yellow to dark orange. Lily responded, “Oh...” He explained that this is the property of buffers and how they work.

Daley moved onto step 8 to show the calculation of the final pH in each solution:

	$C_2H_3O_2^-$	+	H^+	\leftrightarrow	$HC_2H_3O_2$
Before	80.0		30.0		80.0
After	50.0		0		110.0

He showed them the calculations to obtain the values in the table and finally the pH:

$$5 \text{ ml} \times 6 \text{ M} = 30 \text{ mmol}$$

$$pH = 4.74 + \log_{10} [50.0]/[110.0] = 4.40$$

He pointed out that the pH changed from 4.74 to 4.40, which was not much. He asked if they could see how buffers work mathematically. The ratio of the base and acid changed a little and the overall pH did not change much.

Next, he moved on to the calculation for beaker C, assuming that one drop of acid contained 0.05 ml.

$$0.05 \text{ ml} \times 6 \text{ M} = 3 \text{ mmol}$$

$$[H^+] = 0.3 \text{ mmol} / 400 \text{ ml} = 0.00075 \text{ M}$$

$$pH = 3.12$$

He pointed out that the pH changes from 5.00 to 3.12 with one drop of HCl.

He moved onto step 9 to add methyl red to B. Methyl red appeared pink or purple.

He wrote that D was not a buffer while B was a buffer. Alizarin yellow was added to D

and it was yellow. He added NaOH quickly to B and the color turned paler. Lily predicted the color would not change much and she was right. He added the NaOH to D and the color changed from yellow to peach. He proved the point again that buffers resisted pH change. He told students to work on step 11, which was to calculate the pH of the solution. He said they should be able to do it now.

As the students worked on the calculations, Daley also wrote the working to step 11 on the whiteboard. Some students referred to his answers, some copied the answers, while some work on their own.

	HC ₂ H ₃ O ₂	+	OH ⁻	→	C ₂ H ₃ O ₂ ⁻ +	H ₂ O
Before	80.0		30.0		80.0	-
After	50.0		0.0		110	-

$$pH = pK_a + \log [B]/[A]$$

$$pH = 4.74 + \log [110.0]/[50.0]$$

$$= 5.08$$

$$(B: pH \ 4.74 \rightarrow 5.08)$$

$$\text{Solution D: } 0.05 \text{ ml (1 drop)} \times 6 \text{ M} = 0.30 \text{ mmol}$$

$$[\text{OH}^-] = 0.30 \text{ mmol} / 400 \text{ ml} = 7.5 \times 10^{-4} \text{ M}$$

$$pOH = 3.12$$

$$pH = 10.88$$

$$(D: 5.08 \rightarrow 10.88)$$

He briefly went through the working and emphasized the pH increased many times more in the non-buffer solution D. Before he ended the class, he gave additional examples of buffers used in research, blood, biochemistry, and cell growth.

Vignette 6—The revised curriculum on buffers [March 9, 2010].

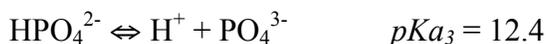
Choon was in charged of the acid-base unit and introduced a new buffer laboratory activity in replacement of one above. Below was the task written for students:

You are working at the IMSA aquarium and your job is to prolong the life of three varieties of genetically engineered fish. The fish optimally live in 0.200 M phosphate buffer at different pH levels as indicated in the table below. The combination of the weak acid and the conjugate base concentration should add up to 0.200 M. For example, 0.120 M of the weak acid and 0.080 M of the conjugate base form of the phosphate will give a total concentration of 0.200 M phosphate buffer. The optimal buffer conditions for survival of each variety of fish are as follows (you want to make 25 ml of this buffer):

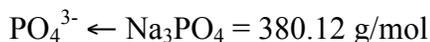
Fish	Optimal Phosphate Buffer pH
A	7.9
B	3.5
C	11.8

Your instructor will assign you the fish that you need to make a buffer for. You may use the Henderson-Hasselbalch equation or an ICE table for this task. You will need the following information. $pK_1 = 2.15$, $pK_2 = 7.2$, $pK_3 = 12.4$. The most acidic form is H_3PO_4 and the most basic form is PO_4^{3-} . In the space below, show calculations for how you will make your buffer. Have your buffer plan approved by your instructor, and go into the lab and make it!

Daley wrote on the whiteboard three equilibria for the triprotic acid. On the left is information on molar mass which Choon had written (but contained several errors):



Molar masses:



Daley had the students read the activity first then he began his discussion.

Daley began the discussion with a recap of the concept of buffers and calculations of pH . Below is the conversation between Daley and his students.

Daley: Number 1, what is a buffer? Anybody, in your words, if I ask what is a buffer, what would you say?

Stacy: A mixture of acid and base.

Daley: That's what it has in it. It has in it an acid [Stacy: conjugate base] and the conjugate base. That's what's in there. Okay. A buffer has acid and conjugate base in it. Okay? That's the first thing. What does it do?

Stacy: Resist change in pH .

Daley: A buffer resists the change in pH . Alright? You guys remember the Henderson-Hasselbalch equation? Everybody should have it up (Daley pointing to his head) here right now I can imagine. I will start with pH [Ss: Equals] equal to [Ss: pK_a plus log of base over acid].

[Daley writes the equation on the whiteboard.]

Daley: That's the Henderson-Hasselbalch equation. This is an awesome equation that works with buffers. Because in a buffer you have a mixture of acid and conjugate base in solution, you can use Henderson-Hasselbalch to determine the pH of the buffer. Okay? And what can you guys tell me about the concentration of acid and base in a good buffer? What is true about the relative concentration of the two? Any ideas?

[Silence]

Daley: Does it seem like a good buffer should have a lot of acid and just a little bit of base? Or the other way around, it should have about

equal amounts of acid and base? What do you guys think? What is a buffer suppose to do? If I add acid, it's supposed to resist the change of pH , how is it supposed to do that? Base. If I add base it should resist the change in pH . What's in there to react with the base?

Students: Acid.

Daley: Acid. Isn't it intuitive that it seems like about equal concentration of acid and base would be the best buffer? What does that mean when we have exactly equal concentration of acid and conjugate base? What would this whole term ($\log [B]/[A]$) drop to?

Students: Zero.

Daley: Zero. So a really good buffer, the pH of the buffer is approximately equal to the pK_a of the acid. Alright. So let's talk about this. What is the pH we're supposed to work with today? There are three buffered solutions. Each suitable for different genetically engineered fish at IMSA. So there is Fish A, Fish B, and Fish C. they need different pH . Let's see. Fish A likes 7.9. Fish B really likes acidic pH of 3.5. And Fish C likes 11.8. That is really really basic. So let's pick on Fish A for a second. Fish A. if we want to make a buffer of pH 7.9, which one of these acids would be best?

Stacy: Second one.

Wilfred: Second.

Daley: The second. Why?

Stacy: The pK_a is already 7.2.

Daley : The pK_a is close to the pH we want. Okay, by the way we're going to be working with some variation of phosphoric acid today. Look at phosphoric acid up here. It is not monoprotic. It is not diprotic. It's actually one of the few acids that is triprotic. Okay. If we want to make a buffer with a pH around two, phosphoric acid along with its conjugate base may not be a good choice. If we want to make a pH of buffer around 7, the second system is a good choice. If we want a buffer with a quite high pH of around 12, the third acid conjugate base pair appears to be a good choice. Okay. So what are the rules for making up the buffer today? Let's look at the board. First of all, we're going to be working with one of these two. You know why we're not going to have anybody do this one? Because we don't have any phosphoric acid. Okay, so it means we're not

going to do that. It means for each group I'm going to assign either A or C to do. So what are the rules? What is the total volume of the buffer?

Students: 25.

Daley: 25 ml. To be honest with you, I don't really care much about that rule. If it's not exactly 25, I don't care. But that should be around 25 ml. Okay that's the second rule?

Students: 0.2.

Daley: Yes, the total concentration of the two salts in the solution of the acid conjugate base solution should be 0.2 molar. So I'm just put [Daley writes the rules on the whiteboard] the total concentrations equals 0.2. Are there any other rules in there? The winner is the group that makes the buffer they are assigned and then we're all going to bring our beakers up here. And I'm going to standardize the electrode. And we're going to project the *pH* reading on the screen. And we're going to measure each group's *pH*. Okay, whoever comes closest will win a chocolate bar. Alright.

Daley assigned the buffer to each group which they had to prepare. He briefly summarized the steps:

Daley: You need phosphate, PO_4^{3-} . The molar mass is up here for you. This is a hydrate, so the bottles you're going to use are at the back tray on the second bench. They look like white powder. So the three salts you're going to use today will be one of these three. The molar mass is already up here for you to figure out how much you need to mass out.

Later, Daley repeated the overall steps again:

Daley: It seems like ... what we need to do here? Figure out the ratio of base to acid right? Then set the ratio such that the total concentration of acid and base add up to 0.2 molar. So there's a little bit of algebra there. And then figure out what mass you need to mass out. Okay, listen to me you do not use the logger pro to adjust your *pH*.

Students: Aww....

Daley: But, that's because this is a contest. In the real world, if you're going to make up a buffer for a fish, the survival of this fish depends

on the pH of the buffer. You would put in your acid and your conjugate base and then what would you do? You put an electrode in and you add a little acid or base to get right where you wanted. Correct? But we're not going to do that today. You're just going to bring it up, you're going to hand me the beaker. The first time you're going to know what the pH is during the contest. That's what we're going to do. What would be a good way to measure whether our buffer works well?

(...)

Daley: We don't have any genetically engineered fish. What should happen if I add one drop of 1 molar hydrochloric acid to your buffer?

Students: Not much.

Daley: Not much. So we'll test the buffer by adding some acid and base to your buffer.

The students started the calculations at 9.57 a.m. The students took a really long time to calculate. Those who simply applied the Henderson-Hasselbalch (HH) equation arrived at the concentrations of the acid and conjugate base but did not know how to proceed to find the mass or did not know what to do. Edison and Nevia approached Daley later for him to explain and he did. Some students showed him their working and he had to tell them how to proceed. The Isaac, Igor, and Alan worked together and approached the problem in the same way as the other group consisting of Wilfred, Jackey, and Warren. I watched the later group perform their calculations.

Wilfred wrote this out:

$$pH = pK_a + \log [B]/[A]$$

$$7.9 = 7.2 + \log [B]/[A]$$

$$[B]/[A] = 5.01187\dots$$

$$x/0.2-x = 5.01187$$

He found the concentration of HPO_4^- and H_2PO_4^- . They thought they had to use the 'ICE' table because they misread the instruction to use both. At the end of it, they were confused because at one point Warren found that they had five variables to solve. As he eliminated each one, he found that they returned to 0.2. Daley overheard Wilfred said the 'ICE' table and commented that they did not have to use it. The students were delirious and burst out laughing. Still they did not see the solution. Isaac and his peers were also confused and showed Daley his working. Daley explained to him how he could proceed from the concentrations. I commented that Wilfred and his peers were doing the same thing Isaac and his peers did. Daley laughed and he explained. This was to him a good learning point. Daley gathered his thoughts and explained slowly to the students. He did not anticipate this question because his previous class just solved the problem in a few minutes using HH and completed the task. He went to the whiteboard and wrote a general K_a expression: $K_a = [\text{H}^+][\text{A}^-]/[\text{HA}]$.

Daley: Guys, the K_a expression for an acid is the concentration of H^+ and conjugate base over acid. You use an 'ICE' table. You end up with $K_a = x^2/0.500-x$. Let's say the concentration of the acid was 0.5. You set up an 'ICE' table to calculate the pH of a weak acid and the expression is this right? Henderson-Hasselbalch calculates, Henderson-Hasselbalch is derived from this. You guys are, maybe think of this for a minute. What assumptions are we making when we use Henderson-Hasselbalch? When we plug in concentration of acid is just 0.5? What can you guys tell me about a weak acid? The value of x compared to the concentration of the acid really was?

Jackie: Small.

Daley: Small. Therefore, we're making an assumption that x is so small that this $(0.5-x)$ is just 0.5. When you use an 'ICE' table you don't make the assumption. When you use Henderson-Hasselbalch, you make that assumption. (...) Is that approximation justified or not? It is. Guys, that day one student came to me and said to me, "I don't understand Henderson-Hasselbalch" because when you do the 'ICE' table, we're subtracting x from the concentration of the

acid. But the assumption when you use Henderson-Hasselbalch is that x is very very small compared to concentration of the acid. That is true for weak acid. So Henderson-Hasselbalch is a set of approximation that is good to about 10^{-3} . The approximation works really well. I'm going to say it again this [HH] comes from here (Daley points at the K_a expression.). If I take the negative log of everything and do it algebraically, you get that. And then when you plug in the concentration of base over acid, you're assuming in you're plugging in 0.5, not $0.5-x$. it works. I did not talk about it the other day. It sounds like that's what you guys are thinking. You can directly use Henderson-Hasselbalch to get this ratio. Are you making an assumption? Yes. Does the assumption work? Absolutely. The assumption works on any weak acid with K_a to 10^{-3} or smaller. 10^{-4} , 10^{-5} . Well what are we working with here? We're working with something to 10^{-7} , 10^{-12} . This assumption works really really well. There's only a couple of weak acids in this world where weak acid does not work well with Henderson-Hasselbalch. And we're not dealing with them here. If I tell you we did, you'll need to use an 'ICE' table. So I need to do is to use Henderson-Hasselbalch to find the ratio of base over acid. It's pretty straightforward right? And set it up so that the base and acid adds up to 0.2. Get into the lab and get this buffer.

To begin the contest, Daley connected his computer to a pH electrode and projected it on the screen so that students could observe the pH readings. Galenia recorded the pH values on the whiteboard. First, Daley told the students that he calibrated the pH electrode.

- Daley: I have calibrated this carefully. Now I want to show you guys something. Here is about 20 to 25 ml of water. How about one drop of one molar hydrochloric acid. (Daley adds one drop of acid into the beaker).
- Students: Wow.
- Daley: About three or four magnitude. Clearly, water doesn't resist the pH change very well. Now your buffer should be better than that.
- Students: Oh!
- Daley: It was good in the last class. Here is some base and water. I add a little base to it. Water. And now I'm going to add five drops of the base because it's only 0.2 molar, so. What happened to the pH ?

Ramesh: Nine.

Daley: It went up. Okay so if you add just a drop of 1 molar NaOH, the pH goes up and that is a dramatic change in pH. Who wants to go first? Okay.

Daley put in the electrode and the *pH* was 6.26 while the desired pH was 7.2.

Daley added one drop of 1 molar HCl and there was no change in *pH*.

Daley: Look, we have a three to four units of pH change when I added one drop. Now I add one drop. Hey everybody. What's the lesson? Buffers work. Congratulations!

Daley tested the other buffers in turn and all of them resisted *pH* change. A few of the buffers had *pH* close to the targeted but they worked well to resist *pH*. Jackie and Wilfred got so high-spirited that they were rallying and shouting for the pH to go higher for their buffer. For the final buffer, Daley poured in the remaining acid to show how the *pH* would decrease dramatically if a lot of acid were added.

Interpretive commentary of vignettes 5 and 6. In the unrevised curriculum, the demonstration was not interactive as students only had to read out the provided instructions. Calculations were required, but Daley anxiously showed his work on the whiteboard before they had time to digest the material and attempt the questions. He was prepared to answer any questions students had and made connections between buffers and real life examples. However, the students did not get to prepare the buffer. They passively sat at their desk watching Daley mixed the acids and bases, took down calculations, and attempted to do some on their own.

Choon revised the acid-base unit to replace the demonstration activity with a hands-on activity. She described the new laboratory activity as inquiry. She explained,

Like when we get to the buffer lab we told them okay, based on everything you've learned go ahead and create like this buffer. And then I want this concentration, I

want this pH, and go write the procedure exactly, show me the calculations, go to the lab, see if you did it right. And I think previously we were used to telling them, okay add 30 ml of this, 50 ml of this concentration of this to make, and then see if you get this *pH* but this time they have to figure things out so I think it was a little bit more challenging. (Choon, interview, May 7, 2010)

The students had to work in groups or with their partners to calculate the amount of acid and base to combine. Again, they combined their knowledge of stoichiometry and buffers to perform the calculations and observe what was meant by ‘buffer strength’ or ‘buffer capacity’. In both cases, the instructions were clear and the goal was known. However, the laboratory design was not coherent with Daley’s idea. He wanted pre-laboratory and post-laboratory questions which encapsulated all the concepts he wanted students to learn, but there were none.

However, in the process of enacting this new activity unprecedented learning opportunity was created. Six students did not pick up Daley’s cue to use the Henderson-Hasselblach equation which was the direct way of determining the amount of acid and base to combine. They started from first principles, which confused them. Daley quickly identified this opportunity to explain the fundamental difference between using the Henderson-Hasselbalch equation and first principles to calculate. His knowledge and years of teaching experience enabled him to troubleshoot quickly, help students learn something valuable, and proceed with their work.

In comparison, Reina, made this activity optional for her students. She said, “If for any reason, because you didn’t finish this, because you didn’t finish the lab report you didn’t get to do this, it’s okay” (Reina, lesson observation, March 9, 2010). She used the curriculum time for students to complete their previous laboratory reports originally assigned as homework. Her priority was for them to ask questions for clarification of the

concepts previously taught. Students who had time and wanted to try the buffer activity could verify the pH of their sample directly with a pH electrode. Only two students attempted the experiment, but did not succeed at getting the buffer they wanted. This lesson was a missed opportunity for students to learn how buffers could be made using two methods. Reina saw herself as playing the role of the “mother hen”, so she would closely monitor and approach students. This contrasted with Daley, who put the onus on students to approach him for consultations or seek their peers’ help.

Resistance and Ongoing Change

Daley’s earlier tensions in his high-wire walk were not evident to him. As he engaged in curriculum planning with his colleagues, interacted with other social agents, and enacted his revised curriculum, existing tensions evolved and new ones emerged as more imperative and limiting.

A curriculum change Daley and his colleagues agreed on was to increase the assessment weight from 40 to 70 percent to increase students’ accountability. This change was not well received by the faculties. He met with resistance from other IMSA staff who questioned the fairness and contradicting goal. He said,

And then some people in the academy not even in the science department they’re not chemistry teachers, we had to present our changes to the entire faculty, there were faculty who felt it wasn’t fair to students to grade weight 70 percent tests. Their point was how can you say you’re making the course lab based then you give them a test at the end of the unit and the tests make up 70 percent of the grade. My answer to them is that the lab is how you learn the material. And the concepts. Plus we did have lab practicals in a number of our tests. (Daley, interview, May 21, 2010)

Some students argued higher assessment weight encouraged more cheating cases. Daley agreed this could be a cause of cheating but defended,

The more pressure on the test, will students be more inclined to cheat? Sure. But increasing the, I'm not going to back down just because students it encourages cheating. The answer to that is it's supposed to encourage you to learn the material. Cheating is wrong. (Daley, interview, May 21, 2010)

Daley insisted the assessment weight should be increased for students' accountability. He noted this had become an issue of contestation which needed review after one of curriculum change. He would consult the other advanced chemistry teachers, but said, "I will not let it go below 60 percent if one of the teachers wants to lower it" (Daley, interview, May 21, 2010).

Daley was wary of his accountability to students and the need to constantly explain why unfamiliar questions were asked or assessment weight was made in a certain way. In the Fall 2009 semester, some students sent anonymous electronic mails to him using off-campus accounts to question why different teachers recorded their grades in different assessment categories. He investigated and clarified it was an error. He knew this needed serious attention and explanation because students and parents placed a lot of emphasis on grades. Often students would compare grades across the classes and share information on test performances and difficulties. He was aware of student cheating and seriously addressed one incident in Spring 2010 when some students wrote him a note to inform him. Daley would announce to his students the grade average among his classes or cohort so that students knew where they stand. Below is an excerpt of the conversation between Daley and his students one lesson after they completed a test. The students heard rumors that they performed very badly on the recent tests. This had become "the talk of the town". Below was the dialogue between Daley and his students in class when he raised the issue.

Daley: Can I point out something?

Adeline: Okay, I'm scared.

Daley: It's nothing scary. In life do you think if you're going to be paid a lot of money in a job someday where you're just going to be shown to do something repetitive and you just have to do it over over and over.

Mino: Yeah!

Karter: Yea, production.

Daley: That's not going to happen. You have to solve problems.

Minho: No!

Daley: You see where I'm going without going too philosophical?

Minho: You're expecting too much of us.

Daley: No! No, I'm not. I'm not. My feeling is that that is definitely the hardest test of the year. That was by design. The last problem was intended to make you figure out and stretch yourself a little bit to find out how much you know about stoichiometry. Okay. I have not graded it yet. I know one of the teachers had and the grades were pretty low.

Minho: Oh my...

Shaquan: Wait, what is the average?

Daley: I don't know what the average is.

Minho: C+.

Sugako: No curve?

Daley: No. There will not be a curve. Although I talked to the other ad[vanced] chem[istry] teachers about maybe something else.

[Students remain silent.]

Daley: I don't know. I have not graded mine yet. Okay, you guys, there is nothing unfair about asking questions that stretch you, make you extend and apply what you learn. Okay, that is my comment on the test.

Adeline was different from her usual bubbly, jovial, and chatty self. She looked exceptionally worried when Daley sounded serious possibly because she knew she had performed poorly on the test. Daley preempted students' concerns on the impact of the grade on the overall assessment score. He justified the teachers' decisions by saying they were preparing them to face realities expecting them to manage unanticipated events. Daley did not think his students would work in the production line like what Karter suggested. Rather, their job scope would require them to problem solve and act on impromptu decisions. Minho openly resisted in saying Daley's expectation was too high and possibly not something he was ready to handle at this point. Minho, Shaquan, and Sugako were worried about the grades and Sugako tried to negotiate better grades by having teachers 'curve' the results. Daley rejected that request and allayed their worries by saying the teachers had something else in mind but undisclosed. In the following lesson when he returned the test scripts, he said,

I heard words flying around because there are 160 ad chem students, asking the teachers if they should give them an example similar to this in the test. The answer is, maybe not. But that's okay. You know, we don't. In this academy, the way we run classes is not necessary that we show you everything that is going to pop up in the test. Do you guys agree with me everybody? Do you guys agree with me that that test our understanding of what we're doing? It tests your understanding of what we're doing in a problem. I'm leaning towards partial credit if they showed some working of how they arrived at the answer. (Daley, lesson observation, November 2, 2009)

In the actual grading, he gave credit for work shown even when the final answer was incorrect.

Prior to curriculum change, Daley felt the strain in trying to take on all the curriculum responsibilities because he felt his colleagues were relatively new to teaching and the advanced chemistry content. He said,

It's an incredible challenge and puts some strain on me because I'm lead Ad[vanced] Chemistry teacher. I feel responsible for 160 students in the program. I do the lesson plans, share them. All powerpoints they need for lessons like that, I provide because they just don't have the experience yet so they aren't contributing as well as if they are veteran teachers. (Daley, interview, March 20, 2009)

Daley felt responsible for the whole cohort of students even though he was teaching only three out of eight classes. He was the most experienced person in the advanced chemistry team to lead this curriculum change and hence had great responsibilities. This was evident from his description of his roles and responsibilities in the unrevised curriculum. Even though Reina had longer teaching experience in IMSA, she was new to the course. As such, he would share the curriculum materials with the teachers and had them contribute questions to tests and quizzes, but checked on consistency in marking and quickly addressed any rumors of unfairness or perceived teacher leniency.

Daley knew revising the curriculum required a large amount of work and he could not accomplish it alone. In the curriculum change, Daley's identity as the lead advanced chemistry teacher became reconstructed when he decided to distribute his workload and empower his colleagues to become curriculum writers. After summer, Daley shared what it meant to be the 'lead advanced chemistry teacher', but now with a different interpretation. He explained,

That does not really mean I'm in charge. It means I'm responsible for making decisions or at least leading meetings where decisions get made. A lot of the input originally to change the ad chem. curriculum did come from me. I was the one who said we need to change this course but everybody else really bought into that idea. But yes, we got together and I did say this is what I want to work on and these are the units I want to work on and the other teachers picked units and we all agree. (Daley, interview, September 10, 2009)

This reflected Daley's change in ideas about what it meant to be the 'lead' teacher of a course. In this case, Daley's teacher identity had shifted or transformed to become his

subjectivity when reshaped by the contextual factors. Daley realized he could not make decisions alone or had to have his colleagues' consensus and input in order to empower himself to do even more.

By the end of one semester of revised curriculum enactment, Daley realized it was not possible to make the advanced chemistry course open-inquiry because it required manpower to acquire and provide students with resources for their inquiry projects and time. He provided his reasons:

[I] think what is really difficult is that when you're doing true inquiry where every student is doing their own lab. Well, we don't do that in ad chem. We can't just say okay each of you design your own kinetics experiment. Whatever you want to do and I'll get the materials for you. It'll take us one semester to do that. So here is a class where we do that—MSI. (Daley, interview, January 6, 2010)

Hence, advanced chemistry was not the appropriate space for doing true inquiry because the time had to be spent on content teaching to prepare most students taking AP chemistry at the end of the second semester. Methods of Scientific Inquiry (MSI), a sophomore (Grade 10) core science course, was the space to do inquiry because there were supporting laboratory staff and no examinations. As such, he corrected that it was more appropriate to say he wanted to make the advanced chemistry course more laboratory-based curriculum rather than inquiry-based as the laboratory activities were more prescriptive in nature. He said,

Ad chem, even though we say we're doing inquiry-based learning, you know, I'll always call it more lab-based learning. I, I think it's fair to call ad chem or lab-based class. I think it's a little bit of a stretch to say it's a lot of inquiry-learning because the students are all doing the same job. They may do it differently. Like the kinetics lab, they could make up their own, they make the decision to make up their dilutions. The same with the spectrophotometry lab, they made their own, determination of how to make the dilution series. But they are all working with the same chemicals, the same spectrophotometers, so that's not that hard. It's when you get 12 students, or 20 students or 30 students all

doing their own, completely own project, that will be very difficult to manage. (Daley, interview, January 6, 2010)

Daley did not think it was possible to have an inquiry curriculum and do content teaching at the same time; having one would compromise the other. He said,

I don't think it's possible in ad chem for the reason, for reasons of cost, safety, and time. You know, there is still a trade off between inquiry and covering a certain amount of content. And I don't want to completely throw content out. I'm not all in favor of "we got to get through all of this because it's on the AP test". (Daley, interview, January 6, 2010)

Prior to curriculum change, he talked about balancing on a tight rope to provide content knowledge and metacognition. He wanted to be able to achieve both, but said he would err on the side of making students think more. He continued to struggle balancing on the tight rope, but felt real constraints when his ideas were put into actions.

Daley had a more positive outlook on the revised curriculum in the first semester.

He shared his reflections after one semester of revised curriculum change:

But my overall feeling of the ad chem teachers who taught last semester was most enjoyable to teacher. Students I think, enjoyed more, still learned as much. Maybe some comments you saw about the book is we didn't throw so many book problems. We try to give them more worksheets we've written or we just use the lab to learn materials. The pre and post lab are really. That's that is a major change. I'm trying to write the labs so that the pre and post labs are the curriculum. (Daley, interview, January 6, 2010)

However, Daley's views on the revised curriculum changed after the second semester of curriculum enactment. Daley said the first semester of curriculum change was more coherent with what he wanted because he was in charge of most of the units. He felt the second semester curriculum deviated from what he expected and noticed the drop in students' engagement levels:

I felt first semester, I saw extremely high engagement levels. Part of that is just the nature of life at IMSA. The students get tired as the semester goes on as the years go on. They get into so many things going on, AP exams, they miss class

because of AP exams. I would say going back to what I said before, I would give us an A for engagement first semester. Engagement second semester was not as good. Better than a year ago? I believe so. Comparing second semester last year and second semester this year, I think so. (...) The second thing we did is that we focused very very hard on embedding, and we did better first semester than second, on embedding the entire curriculum within the labs. (Daley, interview, May 21, 2010)

He noticed some curriculum materials were hardly revised and some of the laboratories did not include the pre-laboratory and post-laboratory questions.

Daley said he would give themselves an A grade because the revised curriculum went according to what he expected, but a B or B minus grade for the second semester. However, Choon had different views on the revised curriculum. Having only taught the second semester, she said, “Some of the things, I think we made students think more. (...) But some of the things I think we made them struggle through rather than okay this is how, just follow the procedure” (Choon, interview, May 7, 2010).

Daley did not voice any issues or problems during their summer curriculum work or after the first semester of implementation. He was happy the other chemistry teachers were on board his curriculum change plans, understood what he wanted to do, and they each set out to revise their designated units. Their agreement to be on board resulted in a small community of resistance and solidarity (Welch, 1985) as its members participated in the struggles of resistance. Giroux (1988) described,

[S]olidarity as a lived experience and form of critical discourse serves as a referent for criticizing oppressive social institutions and as an ideal for developing the material and ideological conditions necessary for creating communities in which humanity is affirmed rather than denied. (Giroux, 1988, p. 217)

However, at the end of the second semester of curriculum change, he was more candid about the issues and problems faced when the contrast became more evident. Below is a

long narrative from Daley's interview on the list of obstacles he faced and what he planned to do:

Agreeing on how much to grade exams. And then some people in the academy not even in the science department—they're not chemistry teachers; we had to present our changes to the entire faculty, there were faculty who felt it wasn't fair to students to grade weight 70 percent tests. Their point was how can you say you're making the course lab based then you give them a test at the end of the unit and the tests make up 70 percent of the grade. My answer to them is that the lab is how you learn the material and the concepts. Plus we did have lab practicals in a number of our tests. So one obstacle is just overcoming fellow faculties opinions and our faculties here in Illinois Math Science Academy are very opinionated. Because they are very bright and they care and so that translates into having an opinion. Another obstacle is students said assessment weighting was only 40 percent last year. So right out the door we have to explain that. Really didn't get a lot of feedback from parents one way or another. We presented our curriculum changes on Parents' Day. I haven't really heard any positive or negative comments from parents. One of the obstacles, to be quite honest and I think this is why the two semesters worked out differently, I think I had a better understanding of what I wanted the curriculum to be than some of the other teachers who are working with me. And so I think probably while everybody tried real hard and did a good job, I think that not everybody really understood how much I wanted the labs to be changed to drive the curriculum. So I think that is probably one of the obstacles. That is one of the reasons why this summer I need to go back and make some of the changes. Because these, these curriculum changes really kind of came from me. And I think I have a very good conceptual understanding of what I wanted to do and, you know, you assume everybody else does but that's not necessarily true. And I'm not criticizing any of my colleagues at all. I understand that some of my colleagues who worked on curriculum last year, they've only taught one year. And so to ask them and come in, at that time I have 16 years of teaching experience, all in chemistry, all at the high school level, I know exactly what I wanted to do. And then a lot of my, the people who worked with me were much, much newer in this business and so one of the obstacles is getting people to understand what we wanted to do. (Daley, interview, May 21, 2010)

Daley had to manage the resistance from colleagues who were “opinionated” or had hubris of their own. Earlier, I argued Daley had this quality too and in this case, he had to manage others' hubris. This skill was a form of teacher agency Daley had to develop in the process of doing curriculum reform. He had learned to defend his decisions and

actions, and to ward off opposition. While his colleagues appeared to understand what he wanted to achieve, the actual written revised curriculum turned out to be different.

At the end of the semester, Daley admitted to a “change of heart” on what he wanted to achieve for the inquiry curriculum:

Yeah, I think I really, really had a change of heart in a sense, not to completely throw you off on this but I guess inquiry was probably too strong a word all along. I think lab-based is a much better way to put it. We cannot just turn them loose in the air, in the lab, and say go learn stoichiometry, tell me what you need, and I'll get it for you. You can't just do that. You know graduate students, people working on masters or PhD have difficulty doing that. So they're not the point and we don't have the resources here to do true inquiry in chemistry, plus there is a safety issue. There were a couple of labs that we gave them very open-ended procedures expecting them to figure things out. But usually those were simple labs where you can reasonably expect them to come up with an answer. For example, the air bag lab. We did not give them direction. But that was a reasonably simple idea once they knew what they were doing. But I don't even know if I call that inquiry because they had a definite goal at the end. That was more of an engineering project than inquiry. So I'm going to back down on saying I want to, I guess, I guess I want the curriculum to be lab based and whenever possible make the lab procedures as open-ended as possible so that they have to come up with what they are going to do. To think that you're going to do true inquiry at a junior level class even at IMSA is, is you know, you're not going to cover very much chemistry to do that. (Daley, interview, May 21, 2010)

This narrative was Daley's ‘confession’ of mediated curriculum change. According to Rose (1989):

Confession then is both a communicative and an expressive act, a narrative in which we (re)create ourselves by creating our own narratives, reworking the past, in public, or at least in dialogue with another. When the subject is confessing and creating its 'self'. It seems to feel compelled to tell the truth about itself. (Besley, 2007, p. 66)

Daley ‘confessed’ to the reality of constraints and limitations of his curriculum change plans. He said he wanted to do authentic, true, or open inquiry. However, this was difficult for implementation in a course perceived by teachers, parents, students, and school administrators as closest to AP. Although advanced chemistry was not structured

like AP, it still modeled after AP in terms of the topical units, learning objectives, laboratory design with known or predictable outcomes, preestablished procedures, given information, and written assessments with prescribed options and work. As such, even the air bag experiment, which was engaging, was different from what Daley envisioned. On retrospect, Daley thought it was more of an “engineering project” (Daley, interview, May 21, 2010) rather than inquiry.

Daley said his colleagues did not quite understand what he wanted for the curriculum change. This could be in part due to different understanding of inquiry based on their prior experiences working in different kinds of laboratories which, would then, translate into different curriculum design. For example, Alisa thought she was doing more inquiry in the organic chemistry course she revised and taught. She described her idea of inquiry,

Students could go in and do, determine the melting point of the compound. That's the first lab they did; they first learned how to use the MelTemp [brand name on the apparatus] and then they learned how to do distillation, how to separate compounds from one another. They learned how to recrystallize, how to purify samples because in the synthetic research lab, they make the compound and then they have to purify it because you know it's not going to come out completely pure. So how to get all the lab skills that you know successful organic chemist needs to have. A student could go in and do, determine the melting point of the compound. That's the first lab they did; they first learned how to use the MelTemp and then they learned how to do distillation, how to separate compounds from one another. They learned how to recrystallize, how to purify samples because in the synthetic research lab, they make the compound and then they have to purify it because you know it's not going to come out completely pure. So how to get all the lab skills that you know successful organic chemist needs to have. (Alisa, interview, May 4, 2010)

Alisa's idea of doing inquiry was to have students use techniques in laboratory to determine unknowns or unknown properties. Reina had similar views in that inquiry

involved students thinking and trying out in order to find out the answers to their questions. She said,

[I]nquiry is the way to go. And it really does work when the students do have an opportunity to find answers for themselves, they tend to remember it better. It's as simple as that. If they ask, if they tell me well what is this suppose to look like, I say 'I don't know, you find out'. Right now they are doing a qual[itative] lab. And they have pH paper. And they have a red and blue and they ask me, "How do I use it". I said, "I don't know, but you have acids and bases in front of you so you can just take a moment, and do it, check and you'll remember it." Instead of me telling them in acid it's red and, it's little things like that that they will remember because they did it instead of me telling them. Maybe if I do it they're going to forget it anyway. But the likelihood of them remembering is a lot higher than if I tell them this is going to be red and this is going to be blue. (Reina, interview, May 21, 2010)

Choon worked as a graduate research assistant for her advisor in her doctoral program looking at summer inquiry programs for teachers and students in Chicago Public Schools. She adopted the *Physical Science Study Committee* (PSSC) and *Biological Sciences Curriculum Study* (BSCS) curriculum in those projects. She had also published some papers on her inquiry research work with her advisor. Choon's idea of inquiry was as follows:

Like let them formulating some ideas based on the experimental data. Some hands on experiment. I think that's great. And not to just spoon-feed. This is what you're expected to see and this is why. Like let them figure out a series of questions after they examine the data and analyze. (Choon, interview, May 7, 2010)

Choon felt that some laboratories in the revised curriculum were inquiry, but some were not. She did not like activities that took too much time or produced irregular results. She said,

[I]t took like sometimes too long and, there were some challenges like it takes more time and it becomes a little bit, I don't know, more chaos? Because if we don't tell them sometimes, you just go figure out how this works, or just write your own procedure and then based on what you're trying to figure out, go write

the procedure and then go with the experiment. So that takes time. (Choon, interview, May 7, 2010)

Choon described what she did in the buffer activity class which she felt was inquiry:

For example, when we did like acid-base chemistry for buffer. Like when we get to the buffer lab we told them okay, based on everything you've learned go ahead and create like this buffer. And then I want this concentration, I want this pH, and go write the procedure exactly, show me the calculations, go to the lab, see if you did it right. and I think previously we were used to telling them, okay add 30 ml of this, 50 ml of this concentration of this to make, and then see if you get this pH but this time they have to figure things out so I think it was a little bit more challenging. (Choon, interview, May 7, 2010)

Choon's idea of inquiry was rather close to authentic inquiry involving questioning, students writing their own procedures, carrying out trials, and working hands-on.

However, she was very concerned with the chaos in class, unpredictable, and inconclusive results. She wanted students to have "some ownership of their own data especially if its something that it's good. If it's not clear cut data then it's hard to do that but I like a lot of times I would just say don't open up your textbook" (Choon, interview, May 7, 2010). However, when students did not obtain correct or useful results to work with, she would provide them with data to work on. She said,

Oh it's okay to have bad data. I'm okay with it, if that's the case, they can try to see what's going on here and that creates a room for discussion. And we've some like really good conversation especially if one group test with different data and where the error could have come from. If that's the case, I generally make them share the data on the board so we have like seven different sets of data and they see like, majority of them have this data versus this like different data, we just work with the, I just sort of guide them to the one that they should be working with. (Choon, interview, May 7, 2010)

Choon saw questions as something generated from the activity rather than prepared for students. Hence, that probably explained why the buffer activity had no pre-laboratory and post-laboratory questions. The buffer activity was more guided as the information led students to prepare specific buffers. Inquiry could be experienced and

done in different ways. There was not prescriptive steps or methods to doing authentic inquiry. The experiences and understandings each teacher had in doing inquiry was unique and that possibly contributed different design and enactment of the revised curriculum. As such, the intent of doing inquiry was consistent, but the meanings of inquiry curriculum and teaching were not.

Differences in the curriculum change enactment were probably related to the teachers' sense of ownership. The personal onus one asserted on curriculum change was dependent on how much one saw the curriculum change as belonging to or "owned" by oneself. The other teachers had to prepare their own curriculum they were leading. For example, Alisa was revising the organic chemistry curriculum which she found to be disorganized when she took over the course. This could possibly influence the amount of effort and hence the quality of their curriculum change effort. However, instead of having his colleagues re-vise the curriculum or re-communicating his ideas, Daley decided to take on the revision work himself the next summer. In doing so, he was disempowering his colleagues from having a second chance to rewrite the curriculum.

Students as Interactive Element of Curriculum Change Outcomes

Students' interactions with the curriculum materials are an important determinant of curriculum change outcomes. For example, their interpretation of inquiry and valuing of AP are factors affecting the outcomes of curriculum change. Although all students (except for those placed out) learned and did inquiry projects in their first year, they had different understandings of inquiry. Lily described her research project at Fermi Laboratory as doing inquiry. Barry, Shaquan, and Snehal were three students in Daley's class in Fall 2009 and they also had different understanding on inquiry. According to

Barry, an inquiry activity was one where he would be given a problem and not told exactly how to solve it. In the laboratory, he would have to analyze the data and figure things out especially when the results were irregular. He had experienced messing up his laboratory and finding out a better way to do the experiment to obtain better results. He recalled doing one laboratory activity that he thought was inquiry:

There was the, I think it's called dilution lab, where we mixed together in a solution and took timings of how long it took to react. Most people in the class only measured one time and Nityan and I measured intervals of three-second intervals. So we did what was supposed to be done. But everyone else messed up. But that's okay, because that's learning by messing up. (Barry, interview, December 3, 2009)

Shaquan described inquiry as doing a laboratory and possibly getting confused. He thought inquiry was important, but it required having a teacher knowledgeable and abled enough to guide students doing it. He described what was inquiry,

[W]e'll do a lab and maybe we may be confused with why do we do that, he'll [Daley] kind of lead us to the right direction. He'll just asks us one question and then it'll click and oh, we're suppose to do this, oh, that's the next process of how we should do it. And then even for the last lab we did that we're able to choose our own volumes for A and B. You're able to do your experiment on your own and compare it with other people. So those type of things, showing that this class is more inquiry, like creating your own experience is going to be helpful in future. (...) Try things on your own and being, like thinking about questions that are beyond just understanding a concept but oh how could you apply this in the future and okay why don't you do this in a certain way and why is it different in other situations. To me that is what inquiry is. (Shaquan, interview, December 7, 2009)

At the end of the second semester, Shaquan described inquiry as being “thrown into a situation and with no direction, you have to figure out what to do” (Shaquan, interview, May 7, 2010). It involved making mistakes, trying out ideas to see if it worked, making modifications, and retrying; the process was ongoing.

Snehal, on the other hand, talked about intuition in doing inquiry. She said,

I think inquiry is a lot, I think inquiry is lot of like looking at something completely new and not necessarily knowing what the outcome should be. Like using your own, like inquiry, like your own intuitiveness and trying to see like, what might cause a reaction to occur. How does this type of cancer affect the body. You know there are so many different things that you can do especially with the SIR program. Like that is one of IMSA's main standing points is that you're picking something that you're interested in and following that, pursuing that on your own investigations. So I think a lot of the science classes I took in the first year are inquiry. (Snehal, interview, May 7, 2010)

All three students associated inquiry with doing laboratory activities hands-on, but they had different ideas about inquiry. Barry interpreted inquiry as learning from "messing up" or failures and trying again to get better results. Shaquan thought it was important to have a good teacher acting as facilitator, asking them questions, helped make connections, make their own decisions, think of alternatives, try out ideas, and apply knowledge. Snehal saw inquiry as working with something open-ended and carrying out investigations. All of them had varied, valid, and interesting ideas of inquiry associated from different experiences in school and research laboratories.

However, students seemed to have rather conflicted views on AP. Some students thought AP was important while some said they would not be too upset if they had not attained the maximum score of five on AP. AP was important for Snehal because of college credits, but it was not absolutely necessary for her to have it. She thought her parents would be concerned about AP so she signed up for the AP intersession. Instead, her father questioned her choice over other enrichment courses. Shaquan thought AP was important although his mother was not concerned about standardized tests. On the other hand, Barry did not buy any AP preparation books or place much emphasis on it. He said, "AP is not the primary reason. It's secondary. So it's nice to be able to get five but it won't kill me if I don't." (Barry, interview, May 21, 2009). Edward, Lily, and Barry saw

the advantage of placing out of college freshman courses with AP. Similar to Barry, Edward did not think AP was as important as the IMSA grades and his parents were “less concerned than most other people” (Edward, interview, May 14, 2009). He said,

I think tests and quizzes in class are more important to me than APs or like standardized testing. I think they are more accurate representations of your learning because it, the teachers knows what he or she is teaching the students and then like can formulate a test that will like appropriately test the materials that was being taught and I'm not necessarily concerned with the grades of the tests. I mean grades are important, but I would rather be more able to understand like how to do the problems. Like if I'm taking a test and I don't know how to do something and I kind of like, like figure out the way and kind of remember it at the same time and like "oh, I kind of remember and figure it out". Like from fundamental knowledge then I feel really good. and like even if I don't do that well, like it's okay. So that's like that. And for the APs and standardized testing, I don't know, I feel that it's too standardized. It's just, it doesn't really accurately represent the intelligence of people. Maybe the math section because some of the way the questions kind of, it's more than math, it tests your logic and I guess that is a pretty good indicator of your capacity as a thinker. Then for APs, I don't know, I don't really like the idea of APs that much. They're good to like, I guess they make you look good on your transcript for college and but I think the main concern for AP is so that I can lighten the burden on my parents, like so that I don't have to take as many courses in college so they don't have to pay as much. Like that's the main concern for me, but I think a lot of students here take AP just to have a 5 and "oh I did so well on so many APs, I'm going to get into like the best college" and so they kind of just take it for the test and just for college whereas they should be more about learning. (Edward, interview, May 14, 2009)

But Edward knew some parents were more concerned than his. He heard some students said, “Oh my parents yell at me, you got an A minus, that's bad” (Edward, interview, May 14, 2009). The students might have exaggerated a little, but he felt his parents were less pushy. He guessed that was “because they want me to motivate myself so that I'll be prepared. So I'll be able to do things when I'm an adult” (Edward, interview, May 14, 2009).

The school ambience was unusually tensed during the AP examination week. While the examination was happening, lessons were conducted as scheduled and there

were ongoing quizzes, tests, and homework for the courses. Snehal and Shaquan said they struggled to do everything, leaving very little time for AP practice. Shaquan shared his dilemma in trying to balance all of these:

[B]ecause it's like schoolwork and right after schoolwork I'll do my club stuff because I would tell myself I shouldn't study for AP and stay awake because I would be tired in class. And then I have AP calculus this week so I spent a lot on that. (Shaquan, interview, May 7, 2010)

Another student, Ling, commented that tensions were high in the student dormitories. She saw a lot of students studying; nobody wanted to perform badly on AP. Daley observed the students were less engaged in the second semester of revised curriculum. He reasoned it had to do with students' fatigue as the academic year came to an end and most students had to concurrently juggle with AP and the final examinations. The chemistry teachers decided some of the test grades in the later part of the semester would not be counted in the assessment grade.

Strategies and Alternative Spaces for Curriculum Change

Conscious of his constraints in enacting curriculum change, Daley devised strategies and found or created alternative spaces in his curriculum making such that he could enact changes and fulfill some aspects of AP. Daley conducted AP classes during the intersession—an end of semester program for students to pursue an interest or aspect of learning such as scuba diving, film studies, museum visits, karate, AP preparations for biology, physics, or chemistry. Faculty and non-faculty members conducted the courses. Daley taught an AP chemistry intersession class for the second consecutive after getting the idea from the biology department. He said, “I thought it really sounded like a good idea. You know, it just gets students studying earlier. They buy themselves some AP prep

book. We give them lots and lots of practice materials” (Daley, interview, May 21, 2010).

There were 20 students in his class and the intersession filled up very quickly. Daley said,

It’s a popular intersession. I thought it turned out really well. You know there are a lot of intersessions that are probably a lot more fun. You know, there are intersessions where students go to Spain. There are intersessions where students go on trips. And there are intersessions where students watch movies. They play baseball. So those students who signed up for AP chem[istry] were either very motivated to do well on the test or their parents want them to take it. Ya, so it’s a half-day for five days, just grinding through problems. We always end the day with kind of a fun jeopardy type game on topics that will be on the AP exam. It’s fun, it went well. Student surveys are very positive overall. You know it’s kind of a safety net we give. If we’re not going to teach ad chem like an AP class then at least we give some students the opportunity to take this class. (Daley, interview, May 21, 2010)

Daley helped students to prepare for AP by putting information on Moodle (resource online portal for students) such as recommended study guides, things to focus on learning, methods of studying, difficult ideas to manage, important ideas to know, general idea that’s going to be on the test, and skills needed to do well. He printed past year practice papers for the students to work on. He would even offer his predictions on the type of questions asked in AP. For example, he said,

I can tell you, I know the first question on the AP exam free response is going to be equilibrium question. I know the first question of part 2 of the free response is going to be predicting reactions and almost always precipitate reaction. So let me show you one more thing you need to know how to do. That is to write what is called the net ionic equation. (Daley lesson observation, February 5, 2010)

Other than the AP intersession, Daley also made sure students were prepared for the tests, quizzes, and examinations. The teachers would give formative quizzes and review questions which covered the concepts that would be tested in the examination. At the end of each semester, there would be a review packet for students to work on. In the unrevised curriculum on kinetics, Edward said the quiz was easy because they were mostly assignment questions. Daley told the students, “My job is to get you ready for the

test in the way you want” (lesson observation, September 24, 2009), so he would post answer keys on Moodle or the chemistry board and prepare questions to help students focus on what they need to learn. When a question was noticeably different or new to students, Daley would make an effort to explain why the question was asked.

Overview Synthesis of Chapter 4

In this Chapter, I wove and re-presented data mainly from talking and/or observing Daley, and his students, school leaders, parent, and from reviewing artifacts to create interwoven narratives illuminating the issues and questions raised.

Daley envisioned making the previous advanced chemistry course structured less like AP in terms of content, becoming more inquiry based. He wanted to introduce more open inquiry activities to engage students as active learners in the *doing* process. At the curriculum meetings, the teachers crafted the new teaching and learning philosophy for the course, delineating behavioral outcomes students should demonstrate during and by the end of the course. Structural and some pedagogical changes occurred in Daley’s class. However, the laboratory activities were not inquiry in nature. Experimental goals were given, materials were provided, procedures were detailed, and expected results could be found. By the end of one semester of curriculum change, Daley started calling it more laboratory-based rather than inquiry-based. By the end of the second semester of curriculum change, he said he would “back down” on the idea of an inquiry-based course. His idea of the laboratory-based advanced chemistry course was one with content embedded within the pre-laboratory and post-laboratory questions.

Daley’s teacher agency entailed a complex mix of qualities. His teacher agency was an embodiment of the institutional ‘language’, his social and cultural capital formed

and accumulated over the years of teaching, networking, and studying, his personality as a confident teacher willing to step forth to reclaim his teacher agency to ask for change, take risks, and deal with tensions in his work, and resistance interpreted here as a form of teacher agency with informed sense and courage. His ‘confidence’ was overt and projected more a quality of hubris, something Daley acknowledged was embodied by members of elite institutions, and those highly qualified with ‘PhDs’. His teacher agency was not endowed, imposed, and accepted. Rather, his teacher agency as a delocalized form of abstract power did not reside at any sites or persons. Daley enacted it, hence empowered himself to do what he thought he could do best for his students within the space he identified as permitting his to do so. But some school administrators and teachers (even external ones) looked at what he was doing with a different (political) lens. His identities and subjectivities were challenged and reconstructed in transiting between spaces to perform his curriculum work and teach. In a way or another, his teacher agency was not independent of the structure enabling his agentic power and simultaneously disabling.

Many possible macro and micro factors and forces interplayed in the realm of Daley’s curriculum change. This institutional and larger space of specialized STEM school context presented a highly contested ground of contradicting and conflicting personal, sociopolitical, and sociocultural ideologies interplaying with his personal ideologies on teaching and learning. The implications of this curriculum change especially in this context of specialized STEM schools was huge, but Daley could not or did not want to see it. The primary and secondary structures offered space for him to make adjustments and changes, but not revamp or innovate. Stakeholders (external and

internal) at various organizational hierarchical levels projected different expectations on goals and outcomes of this curriculum change tied to their views on personal and external accountabilities. The habitus remained strong as stakeholders' voices and absent presence reshaped and to some extent distorted his plans. Supportive and favorable conditions (e.g., higher ability students and sufficient resources) were available for his work, but Daley faced other issues and challenges working with these resources school administrators and teachers outside the academy could not see. Some of these challenges were internal contradictions, dilemmas, and tensions in trying to internally resolve the non-complementarity of inquiry learning and standardized testing, but to no avail. This curriculum change was a liberating and restricting high-wire walk; he kept his weight on the rope but he did not exactly conquer it.

Chapter 5

Implications, Limitations of the Study, Conclusion, and Future Work

This is a novel critical case study of a science teacher who initiated and engaged in curriculum reform in a STEM specialized school. To my knowledge, no studies have tracked a teacher in a curriculum reform process prior, during, and after curriculum change in the context of a specialized school. The narratives in this work are counternarratives to existing ones on failures of curriculum reform initiated ‘top down’ by curriculum legislators, curriculum writers, or university researchers, and assessed normatively by external prescriptive goals. I examined the quality of teacher agency grounded in a teacher’s own perception of the ‘goodness’ of inquiry curriculum and his motivation to reform the curriculum in a school claimed to offer its own unique advanced science and mathematics college preparatory courses to nurture gifted and academically talented Illinois children. His initial ideas on the inquiry curriculum reform changed from conceptualization, to enactment, then reflections as several factors and forces played out to reshape, redirect, and distort his ideas.

Many studies (Czerniak & Lumpe, 1996; Davis, 2003; Haney, Czerniak, & Lumpe, 1996) described constrained or failed curriculum reform efforts because of lack of professional development opportunities and support in using the new curriculum materials, deficient physical resources, funding, and time for planning, poor teachers’ beliefs in reform, and high pressure to teach to the standardized tests. While these limiting factors are existent and apparent, Apple (2004) reminded us of invisible factors and forces with absent presence in the structures of schooling. At IMSA, Daley knew he was held accountable to the school’s first charge of nurturing gifted and academically

capable students in mathematics and science. In this climate of high stakes testing, his accountability needed to be concrete. Prior and after one semester of curriculum change, he claimed not to have met any obstacles or tensions in revising the curriculum. Much later, he revealed issues and problems faced at the initial stages, especially in explaining his plans to his colleagues. The critical stance was honed as I listened and observed more carefully to elicit nuanced meanings in actions, interactions, and conversations.

I positioned Daley as the knowledgeable individual having the epistemic privilege of *knowing* the context and students well and informing me as an external graduate student researcher and previous high school chemistry teacher on how he coped and maneuvered through such a controversial process. I tried not to objectify him as a knowledge ‘case’ to impose my views or theories on curriculum making, teaching, or learning. Rather, I engaged him in the process of thinking, reflecting, and articulating his plans and enactment. Hence, my research and his curriculum work informed one another as we constantly talked and shared our views on the lessons.

Here, I framed Daley as an oppressed individual and professional in the educational arena whose work was often shaped and distorted by many practical and real constraints often related to sustaining or improving ‘deliverables’ or “measurables” for internal and external comparisons. Daley thought he could change an existing curriculum to make it more open-inquiry and less like AP; he went about planning it with his colleagues, carried out their revision work, enacted the revised curriculum, and realized he could not completely fulfill what he envisioned. Some of his thoughts differed from the school administrators’, parents’, and students’ expectations. Hence, this teacher stood out as a unique and valuable case to understand and analyze what critical issues,

difficulties, challenges, and tensions he experienced and managed given the conditions embedded in this socioculturally and sociopolitically contested structure.

Surfacing and illuminating insidious and non-apparent issues opened a new arena of conversation on better or alternative ways to empower teachers or become self-empowered. In valuing the teachers' knowledge and experience in such a process, deeper insights into the processes of curriculum making could become enlightening and informative for educators trying to understand what necessary conditions are needed for successful curriculum reform. The process is inherently transformative and provokes dialogue and actions. This study exposes many ironies and contradictions in doing teacher-initiated curriculum reform in a STEM specialized school. In the next section, I will use these ironies and contradictions to suggest some implications of this study with the hope of furthering extensive dialogue with interested audience. This includes teachers who are thinking of initiating and making curriculum changes, school administrators and curriculum legislators who are supportive of teacher-initiated curriculum reform, and educational researchers interested in examining teacher agency in schools not subjected to statewide high stakes accountability.

Implications of This Study

First, teachers, school administrators, parents, curriculum legislators, and educational researchers often have misunderstandings of the nature of teacher agency in a specialized school. My own and Daley's experiences at the transitory phases illuminated what people perceived about specialized schools. I recalled my previous colleagues congratulating me on my new teaching position at the new and first mathematics and science academy in Singapore. They described it as "greener pastures" envious that I

would have less student disciplinary and motivation problems. They said I could relax and teach less since the students were gifted but cautioned me the challenging questions students could ask from hearing stories of students in other gifted schools.

Daley's previous colleagues envied him for having to teach only 12 hours a week and the principal saw it as an advantage IMSA teachers have to be able to do curriculum work. However, my experiences and Daley's experiences teaching at specialized schools proved to be different from these rumored views. We faced students' motivational and disciplinary problems, spent more time writing the curriculum (especially in my context where the school curriculum is divorced from the national curriculum) and setting up laboratories, and devoted more after class hours mentoring students in science research projects. Some students and parents showed more interests and talents in subjects other than chemistry and some were more concerned about grades than learning for understanding and applications. It is also often misconstrued that teachers in specialized schools are not subjected to standardized testing and have complete agency to 'do whatever they want'. There is a dialectic relationship between teacher agency and structure—one that I have often described in this study as 'circumscribed'. Daley's narratives show us how teacher agency is enabled but also limited by many factors and forces in the structure of IMSA. These have strong and influential historical, social, cultural, economic, and political links related to the existence and sustenance of such schools.

In my own experience, I recognize the 'freedom' I had to plan, design, and write a brand new curriculum for the new school, but it was a process of struggle, dilemma, confusion, insecurity, contradiction, and conflict similar to Daley's experience. I did not

have an example to reference or someone to consult as I was brought in as an experienced high school chemistry teacher who was supposedly familiar with the high school chemistry curriculum. Feeling that I needed some concrete structure to begin my work, I adapted ideas and materials from my previous school. I had to deliberate on the levels of difficulties, the syllabus, activities, assessment, grading, and so on. I was aware of the high status this school had and the need to have external benchmarking using AP. Eventually, I decided the curriculum content should minimally include and cover content beyond the national (General Certificate of Education Advanced level) curriculum and AP (optional but highly encouraged for students). This, I believed, could provide a sense of security to students, parents, and school administrators, and make it easier to justify my curriculum design. Similarly, Daley admitted using his AP intersessions as a “safety net” for students who felt insecure or worried and wanted a head start in AP preparations. In both schools, AP was used in external benchmarking to account to the school board, parents, and the external community. The students could use the scores for applications for scholarships and prestigious college admissions valuing AP scores as quality assurance or placements out of college sophomore classes.

AP has practical and symbolic value for different individuals and collective groups. The findings in this study contradicted Schneider’s (2009) study as he claimed high status U.S. schools were abandoning AP. Daley’s feedback from school administrators and teachers at the NCSSSMST conference revealed otherwise. Daley and others in specialized schools for gifted and academically talented science and mathematics students knew the limitations of AP, but acknowledged the practical benefits it offered. Hence, Daley and I faced serious dilemmas in creating the curriculum. The

curriculum we wanted turned out to be unsettling or uncomfortable for students, parents, and school administrators because it was ‘untested’ or different. But both of us sought ways to provide a basic sense of security, so that we could carry out our curriculum work. Our identity was constructed and reinforced in the process. Interestingly, a poster at IMSA hung up on the wall near the entrance to the main hall captured my attention. The title on the poster is, “What is an Individual?” It is defined, “Identity is a process, not an object. All Earth Life is connected through a common ancestry. Each ‘individual’ (each organism)—cow, beetle, daisy, human—is actually a consortium of transformed and still-living other beings”. This aptly captured how our identities were continually changing and remolded as we carried out our work.

Hence, teaching in specialized schools is not better or worse, but different. In the context of national curriculum or standardized testing, the ultimate curriculum goals are clearer. But in the context where the accountability is vague or less assertive, it becomes more ambiguous and controversial. Specialized schools are not subjected to high stakes testing but school administrators and teachers are held accountable for grades. Some chose to accredit their program offering assurance of standardized quality. As such, schools and teachers rarely (if not never) claim whole agency in curriculum decision making.

Second, solidarity is a form of symbolic capital important in teacher agency. The groundwork Daley did in his curriculum change showed how he sought to first establish solidarity (Welch, 1985) among a community of believers in curriculum change towards inquiry and less AP. He presented his curriculum change plan to many stakeholders at school meetings, parents’ meeting, and external conferences to harness more support and

recognition. He knew he could not achieve this goal through individual effort and experienced resistances from some people within and outside IMSA. He engaged his colleagues' help to form a community of common believers and participants of curriculum change.

Daley executed this by relinquishing some of his control and having more faith in his colleagues to participate in revising the curriculum. Although these teachers bought into his idea of inquiry, they maintained their original belief and understanding of inquiry gained as scientists and graduate science students working in real science laboratories. This collegiality established by group consensus allowed the curriculum reform work to start but the changes were superficial. Positive emotional energy (Collins, 1993), mutual focus in participation, synchrony (coherence of participants' practices in interactions), and entrainment (connections or overlaps between chains of interactions) did not occur within the community to result in solidarity or formation of group identity (Tobin 2005). This solidarity was needed for critical action and resistance against the macro factors and forces and overhaul of the curriculum. Daley and his colleagues each had innate and different understanding of what inquiry meant, what was important for students to learn, what problems students faced, how students could learn, and the kind of curriculum change needed. Hence, the outcomes of the curriculum change deviated from Daley's ideals, but this also implied curriculum reform making and teaching were personalized processes resulting from teachers' own constructed understanding, motivation, varieties of professional knowledge, and skills. It was not surprising, therefore, why top-down, mandated, or prescriptive reform failed. The potential of developing this collegiality into solidarity disintegrated when Daley expressed his disappointment in the second semester

revised curriculum and decided to revise some of the units on his own the following summer rather than holding open dialogue or conduct a second chance for the group to re-vise. The opportunities for open critique, professional sharing and development, and more collective action for change was an opportunity missed for developing solidarity amongst this group of teachers which could empower them to act collectively against more dominant structures.

Third, teachers' resistance to school norms and cultures is often interpreted as negative or disruptive. However, Daley was allowed to embark on this curriculum change because the principal valued his resistance to AP as an informed decision based on his professional judgment. Gitlin and Margonis (1995) suggested reinterpreting teachers' resistance as having good sense. They purported developing collective relations where teachers' work together to examine and articulate the implicit insights embodied in resistant acts. As such, teachers can be reconstrued as a group of organic intellectuals (Freire, 1985; Gramsci, 1999) emerging from acts of resistance against the pervasive norms and cultures that dominate and constrain their agency. Teacher resistance is thus a form of teacher agency Here, I argue that teacher resistance is a form of productive power empowering them to do more. I see Daley's call for curriculum change as not only good but professionally informed by his rich personal practical knowledge and experience, willingness to work against the norms by identifying pockets within this pluralized space (Talbert, 2000) and using elements of this to justify his claims.

Fourth, Cuban (1990) and Roth (1988) pointed out how U.S. schools and curriculum had undergone repeated and multiple reform over the years. This wave-like trend was not unique to the U.S. curriculum reform and changes were often introduced

because of premature evaluations and recommendations produced by “experts” who claim such and such a change needed to be done to make teaching and learning better. In this study, I learned from Daley to see curriculum as a living material and curriculum making as a living process. A practical move Daley made was not to make an ambitious overhaul of the curriculum. Rather, he worked with the existing curriculum to revise it and introduce new laboratory activities. Even with changes at a relatively small scale (for a course), the process was fraught with complexities that distorted his teacher agency and outcomes. We could imagine how such complexities would be magnified and intensified if the curriculum change had occurred at a school or program level. As a teacher who had been used to the ‘security’ a national curriculum provided, I had always perceived curriculum to be a static and standardized resource equated with the lecture notes, worksheets, tests, and quizzes I wrote and distributed to students over the years to ensure consistency and content coverage. As a teacher mentor, I had always reminded new teachers to point out the important keywords or working students must regurgitate in the examinations and tests. My own experience as an educator proved initially to be abstract until I had to write my own curriculum and observed Daley revising one in a school that has an established curriculum. Daley’s own interim evaluation also informed him of the changes he needed to make. However, more time was needed for the outcomes of curriculum change to show and for teachers to evaluate the curriculum for their use (Patton, 2008) such as improving practice. Hence, it was not my goal to judge if Daley had failed or succeeded in this curriculum reform because if he was reflexive about what he was doing, then he would always be living in curriculum change and the curriculum he

made would always be regarded as a “living curriculum” (Daley, interview, May 21, 2010).

Fifth, in Schwab’s (1960) examination of scientific papers, he found two distinct inquiry forms—stable and fluid. Schwab’s (1960, 1962) differentiation and description of fluid and stable inquiry offer interesting views on two things: Daley’s curriculum reform process, and his and his colleagues’ conceptions of inquiry. The nature of Daley’s curriculum inquiry into making the advanced chemistry curriculum as an “ongoing process of trying to make the course better” (Daley, interview, May 21, 2010) represented a fluid form of curriculum inquiry involving piloting of some changes in the unrevised curriculum with the “blue bottle mechanism” activity, deliberations and debates, reflections, and extended work for continual change. He made use of interim evaluation findings, informal feedback from myself and students, and observations of students’ engagement to continually assess the changes and think of ways to reformulate the curriculum. Hence, the revised curriculum as “subject-of enquiry” would always be “taken as a probably imperfect image or model of some supposed subject-in-fact and research in the terms dictated by the subject-of-enquiry is pursued with the aim of discovering and repairing its inadequacies and limitations” (Schwab, 1960, pp. 20-21). Hence, additional work or research would always be done to pursue or discover inadequacies and limitations. Daley often gave the example of what students do in the *Methods of Scientific Inquiry* course as true inquiry. He said,

And they learn about the process [of inquiry]. This class is all about the processes in science. We actually teach them statistics. You know t-test, analysis of variance, they design a project with a partner. They carry out a project anywhere from a strip test in the res[idence] hall where they’re testing, they do every tests, they do greenhouse bacteria studies, almost anything we have the equipment and things to do. And actually write a paper, they present it and make a poster there

are scientific meaning. In a presentation like this they probably do a better job than me though. But anyway, we really do have the three main domains of science, if you will, and how scientists go about doing their work. (Daley, IAGC conference, February 8, 2010)

This process of inquiry is similar to what is described in the *National Science Education Standards* (NSES) on inquiry describing inquiry as:

[T]he diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (NSES, 1996, p. 23)

On reflections, Daley claimed he had not managed to revise the curriculum to make it open or true inquiry. But in enacting the trial “blue bottle mechanism” and air bag, and buffer experiments, he had allowed students to test out their assumptions or hypothesis when they suggested temperature was a factor causing the mixture to change color in the “blue bottle experiment”. When some students approached the buffer activity differently, he did not tell them to abandon their method and use the Henderson-Hasselbalch equation. Rather, he was pleased the activity generated new thoughts and approaches which he could then use for additional discussions. At times, he was concerned about positive or accurate experimental findings, but in other cases he was more interested in the process and students’ engagement in thinking. The revised curriculum had elements, components, or the attitude of both stable and fluid inquiry even though it was not true inquiry like what scientists do.

In delimiting his role as a stable inquirer and students performing only prescriptive laboratory activities, he created a space for innovation, creation, adaptation, and change so that his knowledge and practice are not “etched”; extending his own teacher agency by learning from the evolving process. The way he enacted the curriculum

thus contrasted with Choon's stable inquiry emphasizing students getting positive results to work on rather than troubleshooting contradictory results. Schwab (1960) had cautioned, "Consensus on a single pattern of choices will merely enable us to overlook what we have not done in our enquiry. Different principles maximize different dimensions of successful enquiry" (p. 23). The narratives in this study offered a view of multifarious or pluralized patterns of teacher's curriculum inquiry into reform and inquiry curriculum which was an fluid rather than stable imagery or model.

Last, in relating Daley's experience at Lewey High School and IMSA, and his transition to a specialized school to my own experience, I finally understood why I was able to make a similar transition from a mainstream public school teaching the national curriculum to teach in the first specialized mathematics and science Singapore school divorced from the national curriculum. In exercising the social and cultural capital we had acquired and accumulated, Daley and I became self-empowered and empowered by others to do what we aspired. Daley and I had social capital. Being the lead chemistry teacher at his previous high school, Daley had opportunities to 'find' a school such as IMSA which paralleled his personal philosophies about teaching and learning. My social capital existed because of my connections with the chemistry faculty member at the university who was the founding principal of the mathematics and science school. Daley and I had the cultural capital that provided the impetus for "moving". Both of us were valued for our social goods (Gee, 1995)—knowledge and experiences—in teaching high school chemistry. Daley's first task at IMSA was to lead the advanced chemistry curriculum team. He was highly qualified in terms of his content knowledge, teaching, and research experiences. I was entrusted to write the curriculum for Grade 10–12 levels

and lead a team of students in research projects because of my research background as a synthesis chemist. Therefore, we were empowered with greater agency in a school valuing what we embodied. These forms of capital were necessary but not sufficient conditions of our teacher agency and inadequate if not used dialectically with structure.

Limitations of This Study

In this study, I claim to take a critical lens but understanding this as moderated in kind compared to the extreme real political activism and social change critical researchers engage in. *Critical* is also an ideology which “provides a shared body of principles about the relationship among knowledge, its consequences, and scholars’ obligations to society” (Thomas, 1993, p. 17). The purpose of this research is not to ask for social and political change but to interrogate the connections between schooling, history, society, culture, economics, and politics, to introduce some uncomfortable thoughts, provoke some questions, and challenge taken-for-granted ways of thinking about schooling, curriculum making, and teaching.

In addition, some critics may argue that this context and teacher to be different from mainstream schools. However, I argue that specialized schools have a long history in U.S. educational terrain since the beginning of the nineteenth century and more of such schools will emerge with more nations’ emphasis on STEM schools, charter schools, and other privatization efforts. Such political ideas have also ‘infected’ countries in Asia including Singapore and Korea. However, little is known and limited research is done in such schools; which is why this study is important. I learned that constraints in curriculum making found in mainstream public schools in U.S. and Singapore schools are not unique to them. More challenging and insidious forms of power are exercised and

penetrate the veins of curriculum making in specialized schools to make it difficult for inquiry curriculum reform to happen.

Conclusion

In this critical case study, Daley, the lead advanced teacher at the IMSA, set out to revise an existing advanced chemistry curriculum making it less like AP and more open-inquiry. He saw AP as limiting for IMSA students, identified as gifted or academically talented in mathematics and science. He believed inquiry supports integrated conceptual understanding of chemistry and in building metacognition. Tensions were embedded in his curriculum work as supportive and contradicting or conflicting sociopolitical and sociocultural factors and forces interplayed with his decisions. His teacher agency, embodying complex qualities, was both enabled and circumscribed by the structure. The revised curriculum was not inquiry, but laboratory based.

Future Work

Following this research, I want to conduct multiple critical case studies on the nature of teacher agency in curriculum making in a specialized school. I have identified three schools in Singapore as possible research sites. The first school is the top school (Grade 11–12) in Singapore offering six years (Grade 7–12) of education for gifted and academically talented students identified at Grade 7. The curriculum culminates in the GCE A-level examination which students have to take at the end of Grade 12. To differentiate and challenge some of the brightest students in this school, a “gifted academy” was established to offer alternative programs beyond the core curriculum. Teachers who are part of this academy write elective curriculum, organize seminars, and

mentor students who are interested to do science research. The second school is the first science and technology school for students interested in these disciplines. This school is currently in its first year offering a four-year program with emphasis in the applied sciences. Students would sit for the GCE Ordinary level examination at the end of their fourth year. I want to examine how teachers create a curriculum which eventually culminates in a standardized national examination. The third school is the first specialized school in the arts for Grade 7–12 students. I want to examine how science teachers write and teach their curriculum in a context that values aesthetics learning and teaching and incorporates art with science. This school context is also different from the other schools as the students take the International Baccalaureate at the end of Grade 12. These multiple cases would offer diverse sociocultural and sociopolitical contexts for understanding the nature of teacher agency in different structures.

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