Hybridizing Cultural Understandings of the Natural World to Foster Critical Science Literacy

by

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Dedication

To my beautiful wife and daughter, Natasha and Isabelle.

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Table of Contents

Chapter 6: Hybridizing Multiple Discourses:

List of Figures

List of Tables

List of Appendices

Glossary

The following is a description of frequently-used terms in this dissertation.

Choice Text	An out-of-school text selected by a student that was related to both his/her interest and the physics unit (e.g., mechanics, electricity) to be taught.
Community	A *local* community is one where a social group of people has direct and physical interactions with each other. A *distant* community is one where people are affiliated to each other through the sharing of some common practices, identities, and beliefs.
Critical literacy	The understanding that all forms of knowledge and practices are shaped by particular combinations of language and symbolic systems under certain social, historical, and cultural context.
Dialogic other	An intended audience during a dialogue.
Discourse	A construction of some aspect of reality from a particular point of view in terms of particular interests. It is manifested in characteristic patterns in the way people speak, write, think, act, and use various tools.
Funds of Knowledge	The social and cultural capital an individual gains from families and communities.
Habitus	A system of dispositions that constitutes an aspect of a person's identities.
Hybridization	The mixing of two or more discourses within an utterance. This process is shaped by the back-and-forth shifting of one's preferences and identifications between discourses for strategic purpose.
Identification	The performance of certain actions or behaviors that signals one's affiliation to certain communities and recognition by oneself and/or others of being certain kind of people.
Intertextuality	The juxtaposition and linkage of texts. It consists of *manifest intertextuality* where specific other texts are overtly drawn upon within a text, and *constitutive intertextuality* that involves the deployment of less visible elements of discourse drew upon during a text's production and interpretation.

Literacy practices	Social practices in dealing with texts that are connected to a specific form of language within specific social communities.
Media	Plural for medium – a material-technological substance for communication and meaning making (e.g., print, video).
Modality (semiotic)	A resource system or code organized and repeatedly used over time in a community for making meaning (e.g., language, images, gestures).
Multimedia Text-Synergy	See *Text-Synergy*.
Orientational meaning	An aspect of meaning making for enacting stance and relationship toward oneself and other people.
Organizational meaning	An aspect of meaning making for connecting elements together into a broader coherent text or entity.
Presentational meaning	An aspect of meaning making for constructing thematic content about the world or reality.
Text	A specific instance of the discursive practices of a discourse, and a product of textualization where people make their experiences into part of a symbolic system. A text is not restricted to print and language, but can be multimedia and multimodal.
Text assignment	An assignment designed under Text-Synergy to guide students in critically connecting their choice text with the curricular topic.
Text-experience reciprocity	The notion that an individual's text reading and experiential activities form a mutual constitutive relationship within his/her life trajectory.
Text-Synergy	A curricular approach designed and enacted to foster the conditions for a hybrid third space to develop in a classroom.
Textualization	The process where individuals transform part of their experiences into texts through a language/semiotic system.
Traversal	The semiotic and phenomenological trajectory of an individual as he/she moves across texts, settings, and activities.
Voice	An ideological stance toward a discourse that is populated within an utterance.

Transcription Notations

.	Short pause
..	Pause longer than 1 second
…	Utterance or text truncated
?	Rising pitch or intonation
ALL CAPS	Increased volume speech
=	Break and subsequent continuation of a single utterance
[ ]	Start and end points of overlapping speech (for chapter 6 only)
Italic; **bold**	Analyst’s emphasis
(*italics*)	Non-verbal actions (e.g., gestures, gazes)

Abstract

Adolescents are constantly exposed to multiple cultural views of the natural world in juxtaposition with the dominant view of science taught in school. This dissertation explores the interaction of these multiple views, and how they shape students' understanding of and attitudes toward science. Situated in a high school physics classroom, a curricular approach was designed and enacted to open a space in the classroom for the convergence of multiple discourses (or systems of cultural knowledge), and subsequently study how students navigate around them.

Ethnographic and critical inquiry revealed that when two or more discourses about similar natural events or objects (e.g., toss of a colorguard flag, human body) were directly juxtaposed in the classroom space, conceptual, affective, and ideological conflicts were generated for certain students. This was particularly so for students whose embedded experiences and social affiliations within certain discourse communities (e.g., sport clubs, church) led to their preferred ways of looking at the natural world from one particular discourse, and consequently a negative stance toward alternative ways in other discourses.

However, through appropriate pedagogical design and support, such juxtaposition also created opportunities for some students to hybridize different cultural understandings of the natural world as they navigated around multiple discourses. Informed by Bakhtin's

notions of heteroglossia and voice appropriation, the characteristics of such hybridization were found to include: (a) being aware of heteroglossic differences in the use of language, (b) a dynamic shift in identification toward the dialogic other, (c) a juxtaposition of the other's voices in one's utterances, and (d) a momentary suppression of one's preferences, for strategic motives. Not only did hybridization provide a means for some students to construct conceptual knowledge across discourses, but it also helped them develop critical literacy in evaluating how various views and knowledge of the natural world are constructed by and through discourses.

The findings of this dissertation provide insights into hybridization as a crucial mechanism of learning, and provide an alternative but complementary lens for understanding how young people bridge discourses – not as a stable binary but as a dynamic and fluid in-between.

Chapter 1

Introduction

Science and school science are not the only representations of the natural world throughout human culture and history. Adolescents are also constantly exposed to multiple cultural views of the natural world, and not all of them originate from the scientific community. Each one of these cultural views involves a different way of understanding and interacting with the natural world, and consequently relates with one another in complex ways to influence an adolescent's expectation of and attitude toward the kind of school science he or she learns later in life. This dissertation – *hybridizing understandings* – explores these multiple cultural views and how students hybridized them as they were confronted with various ways of representing the natural world.

Rationale of Research

Multiple Representations of Natural World

In today's pluralistic and digital age, adolescents are learning more about science, nature, and technology through their non-school activities and media exposure, and consequently develop certain ideas of and attitudes toward science long before any formal classroom learning. When young people talk about science, for some reasons, it is often filled with fascination and curiosity about the natural world, and excitement about some “cool” experiments and activities. Yet, for many students, once they start taking science courses, their initial excitement fades away and their experiences of science in school are often characterized as “boring”, “authoritative”, or “difficult.” Consider this excitement expressed by Naomi, a tenth grader in a physics class, as she talked about what she watched on television:

> There is a Universe [a science documentary] episode on, and I turn it on to see how it is. And then this is like really interesting. So I watch more of them.. I love space for some odd reasons. It’s one of my favorite things.

Yet some time later, when I asked her what her impression of physics was, she replied:

> Okay. It's not my favorite. Like it's not my favorite.. like. like it's good, but it's like a lot of concepts. I feel like it's more concepts than.. chemistry and you can't even touch chemistry a lot of times cos like it's so small you know.

Given the close relation between physics and outer space, Naomi’s response brought up a paradoxical disjuncture between students’ passionate interests in the natural world and their indifference to or dislike for school science, especially physics. Such disjuncture is well-known among science educators and has been documented in much research. Survey studies on students’ attitudes have repeatedly and consistently found an “apparent contradiction between students’ attitudes toward *science* in general and their attitudes toward *school science*” (Osborne, Simon, & Collins, 2003, p. 1060, *italics* added). This contradiction is most apparent in physics which most students, particularly female students, indicated was their least popular and most difficult subject in secondary school. Given the continuing decline in student enrollment in science among many developed countries, this issue of attitudes and engagement in science is undeniably one of the most pressing concerns in science education.

However, this dissertation is not simply about attitudes and engagement; if what is meant by attitude is just an individual, psychological, and subjective view toward certain aspects of life. Instead, what this dissertation will show is that our attitudes toward certain things, including the natural world, are a manifestation of something much more fundamental. It will show that attitudes are embedded in different “worlds” built and maintained by people in different communities, and that these “worlds” engage with each other in a socio-political structure that extends far beyond the boundaries of home or school. In this sense, this dissertation is also about these multiple “worldviews” about science to which students from different backgrounds are constantly exposed.

As a brief illustration, consider Naomi, this time as she spoke about how evolution was taught in school:

> Naomi: Like everything they teach is like fact. Dinosaurs are millions of years ago… and they teach everything is like millions of years ago... and it's not like it *could* be millions of years ago. They don't know a hundred percent sure that it was millions of years ago.
>
> Teacher: Why do you think scientists, for a writer purpose to include that?
>
> Naomi: Because it is *worldly accepted* now. Since it's more out there and less people are going to church, then like more people are accepting evolution, or it's a *worldly known* fact.

This conversation arose as Naomi, her physics teacher, and I discussed an article she picked up from a creation class she was taking concurrently at her church (for more details, see chapters 4 and 7). What ensued was not about one particular student’s opinionated critique of science teaching in a private conversation. Rather, it involved a multitude of “social voices” (Bakhtin, 1981, 1986) that were circulating in the background, with each negotiating and contending what *science* was and how it should be represented. From Naomi’s point of view, science was not just about some factual knowledge of natural events like “dinosaurs are millions of years ago”, but also how scientists constructed that knowledge and subsequently how they should teach or talk about that knowledge. Of course, a 15-year-old teenager did not just come up with this idea and criticism on her own, but such a dialogue is a typical manifestation of a larger debate between evolution and creationism, and more importantly, the socio-political communities behind those worldviews. In this sense, Naomi was carrying, or *appropriating*, the voices of people she had directly and indirectly interacted with through her church-related participations and readings. For instance, Naomi’s repeated use of the adjective “worldly” came from the Bible that teaches Christians to see themselves differently from the secular “world” (e.g., John 15:19, 1 John 2:15). This was thus an important part of Naomi’s identification that shaped her attitudes toward certain issues, which became relevant as she learned science in school.

What is also interesting is that there is no unitary identification that can singlehandedly characterize who Naomi was and how she viewed science. At the time of this research, not only was she a high school physics learner, Naomi was also a fan of science documentaries, a typical “A” student, an aspiring cardiothoracic surgeon, a cheerleader, and a devout Christian. Such multiple identifications were not limited to just Naomi (although her case was the most contrasting), but could also be seen in many other students who were a car enthusiast, a football quarterback, a colorguard, a science-fiction “geek”, a fan of *Crime-Scene Investigation* shows, an aspiring engineer, or an environmentalist. Each of these identifications involves a different way of interacting with or talking about the natural world, just as science has its own unique and specialized way of talking about it (Halliday & Martin, 1993; Lemke, 1990). In other words, for Naomi and many others, there is always a polyphony of voices that influence their views and expectations of what science is and should be about.

The term *science*, and the way it is used in this dissertation (without quotation marks) is most associated with the modern study of the natural world; which can be further classified into the major branches of physics, chemistry, biology, and earth science. The body of knowledge created by each of these studies involves a particular way of examining and representing the natural world. From a historical perspective, science is also synonymous with western science. Latour (1987) further distinguishes between “science in the making” as the cutting-edge theories, claims, and evidence actively made by the scientific community and “ready-made science” as the theories which are no longer disputed and are thus packaged or “blackboxed” into scientific “facts” for dissemination through textbooks and other public channels. As such, the nature of *school science*, which focuses on ready-made science, is quite different from *science* as practiced by professional scientists in many ways, such as how questions are framed, how experiments are set up, and how knowledge is constructed and validated. Nonetheless, science and school science are closely related because they originate from and are sanctioned by the same community of people.

However, science and school science are not the only representations of the natural world. There are also other ways of seeing and interacting with the natural world throughout human culture and history. Religion is another dominant way of interacting with and thinking about the natural world. In the U.S., intelligent design has even been claimed as a “science” by a substantial population. In other parts of the world, there are also numerous “indigenous sciences” which are practiced and legitimized. The most common example is traditional Chinese medicine (TCM) which invokes a radically different view of how the human body functions and harmonizes with the natural world. From the general public’s viewpoint, there is also the “science” from television and science-fiction, which feeds a dramatized and imagined portrayal of science to uninitiated children and adults. Each of these cultural views presents a certain knowledge of and attitude toward the natural world, and poses challenges to the learning of science which presents a radically different view of the natural world.

The point of this dissertation is not to get into a controversial debate about what can be considered science. As scientists and science educators, we have a clear and strict view of what system of knowledge can be counted as science. We are also in agreement as to what it means to be “talking science” or “doing science.” However, what I am concerned with as an educator is what adolescents think and feel about science in relation to their existing understanding of and attitudes toward the natural world. Mandating students to accept one view of the natural world by brushing aside others as non-scientific, superstitious, pseudoscience, or dramatized science may only further marginalize many of them from the discipline we want them to embrace. This is perhaps happening now as shown by the survey studies on the “apparent contradiction” between students’ attitudes toward the natural world and school science (Osborne, Simon, & Collins, 2003).

Therefore, if we are serious about confronting the continuing decline in science enrollment, we need to be aware of their various cultural understandings of the natural world, and how they may differ from the view of science taught in schools.

Consequently, we need to find ways to address any difference or conflict. (Knowing the students' cultural understandings is different from knowing their prior conceptions, misconceptions, or alternative conceptions. A key difference is that the cultural understandings are attributed to the social views produced, maintained, and contested by various socio-political communities, rather than the undeveloped ideas formed by an individual. See chapter 8 for further discussion.)

Hybridizing Understandings

These issues thus highlight the main problem to be addressed in this dissertation: the disparity between what adolescents are learning about the natural world through their out-of-school *discourses* (as systems of knowledge and worldviews) and what they are learning in school science. With regard to this disparity, there is currently an ongoing debate over whether these out-of-school discourses present opportunities *or* challenges to school science teaching and learning. While some educators assert that science teaching should embrace the non-academic discourses among youths (e.g., B. A. Brown & Kloser, 2009; Elmesky, 2009; Seiler, 2009), others are concerned about the deterioration of science academic standards as a consequence of embracing these non-academic discourses or "creolized science" (e.g., Yeo, 2009). My standpoint on this conundrum is to look beyond the "in-school" and "out-of-school" binary that has characterized the debate, and strive for the "borderlines engagement" or what Bhabha (1994) calls a *hybrid third space* of multiple discourses. Although the notion of third space originated in post-colonial studies, this idea has been pioneered by researchers working to improve educational equity and promote socially-just instruction (e.g., Gutierrez, Baquedano, & Tejeda, 1999; Moje et al., 2004).

As such, this dissertation is first and foremost about *hybridization* or the mixing of discourses. Despite its importance as a way to overcome the binary of the in- and out-of-school conundrum (and many other binaries I will talk about subsequently), hybridization is one of the least understood phenomena in education research. In a pluralistic and globalized world where our lives are increasingly intertwined with others, I posit that hybridization is going to become an important way of life for many of us. As I carried out this research, hybridization became a major theme that emerged from my observation of the students' diverse lifestyle and multiple identifications. However, as our school environment is still very much structured under a Fordist division of specializations, our understanding and fostering of this phenomenon has been limited. Therefore in this dissertation, part of the agenda was to create several conditions for hybridization to occur, and in the process, study what it was and how it developed.

The term "hybridization" may connote to readers a broad spectrum of processes in various aspects and levels of mixing. One likely misinterpretation is the mixing of discourses at a societal level that is responsible for widespread language and cultural change. Another could be the emergence of a new discipline or category of knowledge through a blending of traditionally defined forms of knowledge. These "societal" hybridizations are clearly beyond the scope of my dissertation, given the timescale and setting of my data (i.e., six months in a classroom). Instead, what I am focusing is the explicit juxtaposition of students' various understandings of the natural world gained from their multiple participations (e.g., sports club, church, social media, school science) within a science classroom environment. Through such juxtaposition, I examine how the students were able to consider multiple points of views, synthesize various perspectives, and consequently generate new knowledge and interpretations of the natural world they live in. I use the term “hybridizing understandings” to denote this overall pedagogical approach of considering students’ cultural views and sense-making of the natural world. By contrast, I use “hybridization” as a term for the process of mixing two or more discourses together within an utterance or text (see chapter 2 under review of Bakhtin).

Critical Science Literacy

Hybridizing understandings does not adulterate the discipline of science nor confuse a student’s scientific understanding. On the contrary, as I will show in this dissertation, through sound instructional designs and supports, hybridizing understandings can better sharpen students’ ability to differentiate what science is in relation to other cultural views. As such, the aim of hybridizing understandings is not just about building bridges across multiple worlds nor catering to students’ diverse interests. Instead, the most crucial reason has to do with the rapidly changing social, economic, and political landscape of the “new times” (Hall, 1996). Many educators have argued that, in light of the increasing cultural and linguistic diversity of social practices made possible by technological innovations, the new times will demand critical media literacy that is very different from current school-based forms of literacy (e.g., Gee, 2004; Luke, 1998). This involves understanding that all forms of knowledge and practices are shaped by particular combinations of language and other symbolic systems under certain social, historical, and cultural contexts (Kress, 2003). Given the proliferation of media that today's youths are exposed to, it is imperative that we empower them to take a critical stance toward their sources of information in all disciplinary areas.

Seen from this angle of critical literacy, the disparity between the out-of-school and school science discourses becomes a great teaching opportunity instead of a problem. While acknowledging the various views of the natural world that students have come across through their out-of-school discourses are different from science, there is an urgent need to talk about those differences in the classroom instead of authoritatively brushing them aside as non-scientific. For instance, a creationist text, an article of a racing car, or a *CSI* television episode could be drawn into the classroom conversation to contrast how science is presented in those texts compared to the canonical science they are learning.

This goal of critical literacy is aligned with a vision of scientific literacy to develop well-informed citizens of science. According to Roberts (2007), there are two broad "visions" of scientific literacy. Vision I is concerned with an inward view of science, focusing on internal disciplinary aspects such as its products (e.g., theories, concepts) and processes (e.g., inquiry, argumentation, experimenting), while Vision II looks externally in examining the role of science in human affairs embedded within socio-political issues. Part of fostering Vision II of scientific literacy involves helping students to discern and critique different representations of science made by various social groups (including scientists) as they compete for public attention and resources according to their vested interests. In an information era where all sorts of texts about science, including those with misleading claims, inaccuracies, and overt socio-political agendas, are easily and widely accessible, critical literacy will increasingly become a crucial part of Vision II. It is thus another reason why hybridizing understandings is important in science education.

Purpose & Goals

Thus, in light of the above-mentioned rationale, the purpose of this study was to simultaneously forge *and* study a hybrid third space in a formal academic setting, particularly in a high school physics classroom. (The selection of high school and physics will be explained in chapter 3.) This third space was viewed as a cultural and transformative space opened up through the juxtaposition of multiple discourses brought by the students into the classroom. In particular, I was interested to see how different voices and representations of various discourses could be juxtaposed in a conversation, and subsequently be mutually challenged, reshaped, and expanded to generate new interpretations and critical literacy.

There were two mutually-supporting research dimensions of this dissertation: (1) critical ethnography and (2) curricular transformation. These two dimensions were carried out simultaneously and they complemented each other in the overall purpose of this dissertation. On one hand, to effectively transform the classroom environment so as to foster a third space, one needs to know more about the students' cultural views of the natural world to understand what is being transformed. This was the goal of critical ethnography. On the other hand, for ethnography to be meaningful, it must be anchored by the curricular purpose of improving certain aspects of student learning. In chapter 3, I will discuss further how these two research dimensions were brought together and operationalized in a classroom. For now, I elaborate what each of these research dimensions entailed.

The purpose of the first research dimension, critical ethnography, was to find out how adolescents' out-of-school activities and media exposure were related to the physics topics they were learning. Using ethnographic methods, the purpose was to first examine the students' background, interests, and attitudes toward certain aspects of their life that they drew into the hybrid third space in the classroom. These findings were documented in chapter 4. Following this, the next step was to understand, through critical inquiry, their multiple "worlds", and the associated voices and representations that shaped their views of physics, and this became the purpose of chapter 5.

The second research dimension of curricular transformation involved opening up the space in the classroom for a hybrid third space to develop. This entailed a collaboration with a classroom teacher in developing an unprecedented curricular approach that later came to be called *Multimedia Text-Synergy*. The central tenet of Text-Synergy was to invite and integrate students' out-of-school texts and media into the formal curriculum, and through the process, help them critiqued the various ways science was represented across the in- and out-of-school domains. In this sense, Text-Synergy was the operationalization of hybridizing understandings in a particular classroom setting, and its purpose was to render hybridizing understandings visible for study. As Text-Synergy deliberately juxtaposed multiple texts and discourses in the classroom, I was interested in both the process and outcome of student learning as a result of this curricular approach. The process aspect examined how students navigate around these discourses in their attempts to hybridize, while and the outcome aspect examined the manifestations of hybridization in the students' work and their development of critical literacy. These two aspects were reported in chapters 6 and 7 respectively.

Research Questions

Therefore, in the process of studying and forging a hybrid third space, the specific research questions (RQs) and sub-questions that guided this study were:

1. How do students' out-of-school discourses intersect with the specialized discourse in school physics? (Critical ethnography)
    a. What is the nature of the texts that students read (or are likely to read) that are related to the physics topic?
    b. On what basis do students select these texts, and how do they value and interpret them?
    c. What are the similarities and differences between out-of-school discourses and school physics discourse, and the way the students interpret and value the texts in each of them?

2. How does the juxtaposition of multiple discourses, through the enactment of Text-Synergy, shape the development of a hybrid third space? (Curricular transformation)
    a. How do students navigate around multiple discourses?
    b. How does the juxtaposition manifest in the students' (i) explanatory writing, (ii) critical evaluation, and (iii) attitudes toward school physics?

Overview of Chapters

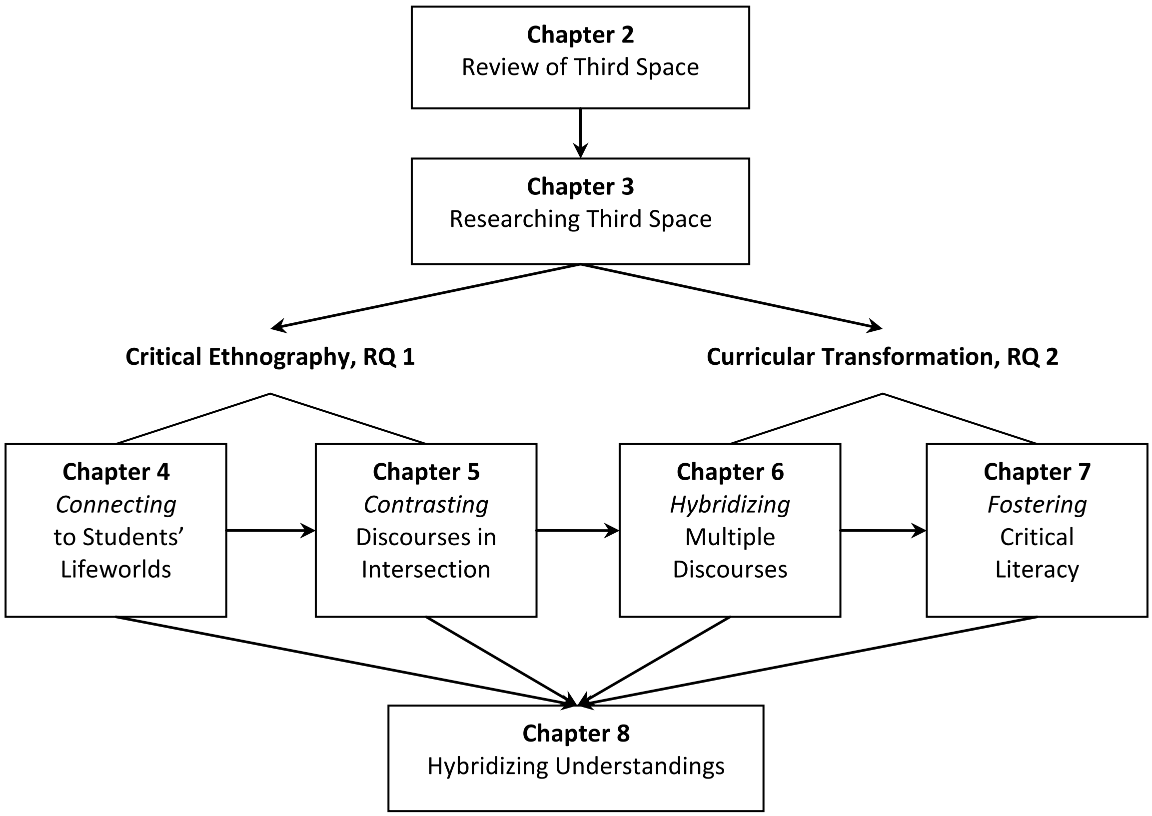

Figure 1. Logic of inquiry and organization of dissertation chapters.

The organization of the remaining chapters in this dissertation follows the logic of inquiry as illustrated in Figure 1. In chapter 2, I review the relevant literature that provides the theoretical and empirical basis of this research. Synthesizing across various perspectives, the purpose is to situate the use of key theoretical constructs within prior research, such as text, literacy, discourse, media, voices, and most of all, hybridity and third space. Besides stating their definitions, I also seek to theorize the relationships between these key constructs. In addition, chapter 2 also identifies research gaps that present further rationale for the importance of this research.

This is then followed by chapter 3, which presents the methodology I used to research third space. This includes a discussion of how I conceptualized and operationalized a third space through the use of design-based research methods (Collins, Joseph, & Bielaczyc, 2004); an elaboration of the curricular enactment of Text-Synergy in a classroom; and a description of the sampling procedures, research setting, participants, data sources, and data analytical methods.

The findings of the dissertation are further divided into four chapters, with two chapters addressing the critical ethnographic dimension of the research (RQ1), while the remaining two the curricular transformative dimension (RQ2). As a rough guide, chapter 4 addresses research question (1a) and (1b), while chapter 5 addresses (1c). For research question 2, chapter 6 addresses (2a) and chapter 7 on (2b). Besides this division according to the two research dimensions, the flow from chapter 4 to 7 also follows an accumulative sequence of findings: from *connecting* to the students' lifeworlds and out-of-school participations in chapter 4, to *contrasting* their various discourses with school physics discourse in chapter 5, to *hybridizing* the discourses as the students navigated around the multiple discourses in chapter 6, to *fostering* critical literacy through hybridization in chapter 7. What follows are brief summaries of the approaches and findings in each of these chapters.

Chapter 4 provides an ethnographic description of the students' out-of-school texts and literacy practices in relation to the topics of mechanics and electricity. It illustrates the rich diversity of the students' lived experiences and cultural capitals that could be harnessed for the learning of school physics. As such, this chapter provides the context and empirical basis for understanding the students' literacy resources and experiences, and how they were connected to their social communities. It also accounts for how an individual's attitudes toward science could be traced to the social voices of one's communities, and consequently how certain established discourses (e.g., sports, creationism) were formed and maintained through this process.

Building on chapter 4, chapter 5 illustrates the nature of these discourses and how they contrast with school physics discourse. Using critical discourse analysis, this chapter further illustrates my earlier claim that the students' attitudes toward and views about the natural world were embedded in multiple discourses. These discourses were sports, automobile, popular science, environment, and creationism. The chapter then provides two detailed illustrations (involving the phenomena of movement and the human body) to explain how the juxtaposition of multiple discourses could give rise to conflicts, both conceptually and affectively, as the students related their out-of-school texts and experiences with their academic learning.

In light of the conflicting discourses revealed in chapter 5, chapter 6 explores how such conflict can be resolved. Focusing on the learning trajectories of two students, this chapter presents in detail the process of hybridization, and how it allowed students to navigate around multiple discourses as they managed a specifically designed assignment of Text-Synergy. Through a fine-grained micro-genetic analysis, it illustrates four characteristics of hybridization and shows how hybridization provided a means for students to navigate the conflict between disparate discourses.

While chapter 6 examines the detailed process of hybridization by two students, chapter 7 looks at the manifestations of hybridization in all the students' work using a mixed methods analysis. It examines the relationship between hybridization and critical literacy, and provides evidence that the juxtaposition of multiple voices in the students' explanatory writing generally led to better critical evaluation of their out-of-school texts. It also presents survey findings on the students' attitudes toward school physics as a result of Text-Synergy implementation. Finally, these findings provide the basis for the concluding chapter where I sum up my thesis about hybridizing understandings and draw implications for theory, research, and classroom practice.

Chapter 2

Theoretical & Empirical Literature Review

The theoretical and empirical basis of this dissertation is built on a synthesis of several research areas revolving around issues of science learning, language, literacy, knowledge, and identity. In this review, I provide summaries of seminal theories and studies from these various research areas. My goal is to first define and situate the key constructs used in this dissertation (e.g., literacy, discourse, text) within relevant theories and contexts, and also to theorize the relationships between these constructs. Halfway through the chapter, I review several empirical studies that inform the conceptualization of my research and, at the same time, identify the gaps in the literature. At the end of the chapter, I review key ideas from Bhabha, Bakhtin, and Latour that inform my theoretical interpretation of a "hybrid third space."

New Literacies Studies & Social Semiotics

Literacy Practices Embedded in Discourses

This dissertation adopts a definition of *literacy* from a sociocultural approach to language and learning known as "New Literacy Studies" (NLS; D. Barton, 2007; Gee, 1990; Street, 1993). NLS rejects the view of literacy as a set of autonomous coding and de-coding skills for reading and writing. Rather, on the grounds that reading and writing are always carried out with respect to a text of a certain type, literacy is conceived as social practices connected to a specific form of language within specific social groups or communities. These practices are always embedded in a *discourse*. Discourses are more than an extended stretch of spoken and written language; they are also related to broad socio-historical constitutions of knowledge, culture, and power relations (Fairclough, 1992; Foucault, 1972; Lemke, 1995). They are the products of social institutions that construct what we perceive as different social entities (e.g., literacy, physics, schooling) and position people in different relationships as various social subjects (e.g., students, scientists). As such, a discourse is also "a construction of some aspect of reality from a particular point of view, particular angle, in terms of particular interests" (New London Group, 1996, p. 25). As there is always a diversity of viewpoints, there is always "a diversity of constructions of various domains of life and experience associated with different voices, positions, and interests."

Discourses are manifested in characteristic patterns in the way we speak, write, think, act, and use various tools. In this sense, discourses are also ways of being "certain kinds of people" that are "accepted as instantiations of particular identities by specific groups" (Gee, 2010, p. 3). These "identity kits" or ways of *identifications* are deeply embedded in our membership and participation in various communities, and learned through our habitual ways of interacting with people in those communities (Bourdieu, 1984; Lave & Wenger, 1991). As such, literacy is also a way with words and symbols that we use to enact certain identities associated with various communities (Heath, 1983; Scollon & Scollon, 1981). Furthermore, Gee (1990) also distinguishes a *primary discourse* as the initial discourse acquired early in life (mostly through our closest community) from *secondary discourses* that are acquired later through our socialization in wider communities, such as schools, clubs, and workplaces. From these distinctions, Gee (1990, p. 176) defines literacy as “the mastery of a secondary discourse.” As there are always several secondary discourses, literacy is also always plural (i.e., *literacies*).

From these perspectives comes the definition of *text*. A text is not just a written or spoken product composed from a de-contextualized form of language, but it is always a specific instance of some discursive and social practices of discourses (Fairclough, 1992). As such, it always shares certain characteristics with discourses from which it is derived and instantiates. This relationship between text and discourse is mutually constitutive; as texts are created through discourses, they are also the ingredients that instantiate, maintain, and transform them. In other words, discourses are abstractions of cumulative instances of using characteristic texts by a community over a long period of time. This relationship is analogous to a weather-climate relationship of looking at the same phenomenon from different time-scales: climate is a generalization of weather patterns accumulated over decades, while weather is an actual instance of climatic trends we experience (Halliday, 1999). Thus, texts and discourses are really “the same thing seen from different points of view” (Halliday, 1999, p.8).

Besides an instantiation of discourse, another important property of text comes from a social interactionist perspective. According to Bloome and Egan-Robertson (1993, p. 29), “a text is the product of *textualization* [where] people textualize experience and the world in which they live, making those phenomena part of a language system.” This implies what counts as a text cannot be determined a priori, but must be contextualized with the things that people do and experience. This mutually interdependent relationship between text and experience will be further elaborated and illustrated in chapter 4. While the discussion thus far revolves around written or verbal language, I will broaden the definition of text to include all semiotic modes of representations.

Multimodality and Meanings

Meaning is not made with verbal and written language alone (Kress, 2003; Lemke, 1998b), but is made with all semiotic systems of representation (e.g., images, gestures, symbols, music). This is particularly so for science, which is never carried out and represented only through language. The study of this multiplicity of semiotic systems in human meaning making practices is the focus of an emerging field called *multimodality* (Jewitt, 2008; Martinec, 2005). The early theoretical foundation that informs this work was derived from Halliday's (1978) social semiotic approach to language. Although Halliday's initial interest was to develop a linguistic framework – systemic functional linguistic (SFL), various theorists in the 1990s began to broaden his theory to include other semiotic systems of meaning. Important examples include images (Kress & van Leeuwen, 1996; O'Toole, 1994), music (van Leeuwen, 1998), movement and gesture (Martinec, 2000), and mathematical symbolism (O'Halloran, 2000). These ever expanding inventories of semiotic analytical tool-kits became instrumental for a subsequent proliferation of works in multimodal literacy and multimodal discourse analysis (e.g. Baldry & Thibault, 2006; Jewitt & Kress, 2003; Kress & van Leeuwen, 2001; O'Halloran, 2006; Royce & Bowcher, 2007)

The term multi-modality arises from the use of multiple *semiotic modalities* in the production of meaning. According to Halliday (1978), a semiotic modality, of which language is the best example, is a resource system organized and repeatedly used over time in a community for the production of three different kinds of meanings. These three meanings were further generalized by Lemke (1998) as *presentational meaning* – for constructing thematic content about the world, *orientational meaning* – for enacting stance and relationship toward oneself and other people, and *organizational meanings* – for connecting elements together into a broader coherent text or entity. These three kinds of meanings are applicable for any type of semiotic modality, be it language or the system of images or gestures. As such, they offer a very useful analytical language and tool for my analysis of meaning making beyond the use of language.

Multi-modality is closely related to but different from multi-media. A modality is a semiotic code and convention system (e.g., grammar) for making meaning, while a medium (media for plural) is a material-technological substance where the modality is modulated and inscribed on. Thus, the same modality can be used in different media; for example, language (a modality) can appear in print on paper, in a digital form on a computer screen, or narrated by a person in real-time or through a recorded video. Conversely, most media are *multimodal*; for example a paper or video can have words, images, and other semiotic forms inscribed on the same medium. Furthermore, the word *media,* besides being the plural for medium (a material-technological substance), also connotes the notion of *mass media* – the representation of public domains through common communicative technologies. These two meanings of media are related in the sense that the mass media always operate within a social system of semiotic modalities and use a material array of media technology (Fairclough, 1995b). Hence, the use of the term *media* refers to these two senses of the word simultaneously.

Therefore, the term *text* as used in this dissertation is not restricted to print and language, but can be both multimedia and multimodal. Similarly, the terms *read* and *write* are generalized to any kind of semiotic interpretation and production respectively, such as watching and making a video. The notion of a *text as multimedia* will be useful in chapter 4 as I examine adolescents' out-of-school texts, which are often digital-based and produced by and circulated through mass media, while *text as multimodal* will be useful in chapter 5 and 6 as I examine how different meanings are made through the use and integration of different semiotic modalities.

In science education, a multimodal approach to classroom teaching was introduced by Kress, Jewitt, Ogborn, and Tsatsarelis (2001) to account for the complex ensemble of semiotic modalities brought together by science teachers to construct particular scientific meanings. In their naturalistic study of four secondary schools, they argue that scientific knowledge construction involves a "dynamic process of transformative sign-making" from one semiotic modality to another. Each modality plays a particular specialized function in representing different aspects of meaning of scientific knowledge. This inherent connection between scientific knowledge and multimodal composition is also substantiated by several researchers working on scientific texts (e.g. Lemke, 1998b; Unsworth, 2001; Veel, 1998). In an analysis of scientific publications, Lemke shows how science concepts are seldom composed of a single semiotic modality, but are "semiotic hybrids" that are simultaneously verbal, mathematical, visual-graphical, and actional-operational. Linking to his notion of thematic pattern (Lemke 1990), science concepts are seen as multimodal semiotic constructions of multiple modes assembled in canonical and institutionalized ways (Lemke, 1998b, 2000).

Informed by these insights, I theorize a *curricular concept* as a network of meaning relationships articulated across multiple forms of representation (Lemke, 2000; Tang, 2011b; Tang & Moje, 2010). What makes a concept "correct" or meaningful is the canonical and recognizable ways of constructing these relationships according to the discursive practices of the scientific community. Hence, what educators mean when we say that students are constructing a scientific concept is the enactment of meaningful actions in an activity (such as talking, writing, drawing, solving problems) to assemble the network of meanings across various words, mathematical symbols, tables, graphs, diagrams, and physical models. Influenced by the theory of multimodality, several studies further investigated how science teachers and students, in various grade levels, used multiple semiotic modalities to construct different science curricular concepts, such as water cycle (Márquez, Izquierdo, & Espinet, 2006), evaporation (Tytler, Peterson, & Prain, 2006), electricity (Prain & Waldrip, 2006), gas model (Givry & Roth, 2006), human body (Pozzer-Ardenghi & Roth, 2007), chemosynthesis (Jaipal, 2009), and work-energy (Tang, Tan, & Yeo, 2011).

Out-of-school Literacies

Multiliteracies

The pedagogical framework of *multiliteracies* plays an essential role in the conceptualization of my curricular approach and research design (to be elaborated in the next chapter). Multiliteracies was developed by a group of scholars known as the New London Group (1996) with the goal of responding to the shifting nature of literacies in a rapidly changing political, economic, and technological world. Multiliteracies is closely related to NLS (New Literacies Studies) and multimodality due to the involvement of scholars such as James Gee, Norman Fairclough, and Gunther Kress who were prominent in developing these fields. However, unlike the research in NLS and multimodality that tends to be more descriptive, multiliteracies involves a more concerted effort to redesign literacy curriculum and pedagogy across the globe to one that is socially and culturally responsive to the changing landscape of the 21st century.

The pedagogical framework of multiliteracies is based on an integration of four factors: situated practice, overt instruction, critical framing, and transformed practice. *Situated practice* begins with a meaningful immersion in the learners' experiences and considers their literacy practices from their primary discourses. This aspect is where most studies in third space emphasize: using student funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992) to support student learning. It is also consistent with current theories and pedagogies of situated learning and inquiry-based learning (e.g., J. S. Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). However, situated practice alone is not sufficient as it does not lead to a conscious control of literacy practices from a secondary discourse, such as science. This is where *overt instruction* is needed to help students bridge their practices with those required for academic learning. Overt instruction does not imply direct transmission to an assumed empty vessel, but rather involves active scaffolding by the teacher to recruit and build on learner's existing literacy practices (i.e., situated practice).

The goal of overt instruction is not only to meet curricular standards and benchmarks, but also to facilitate the development of *critical framing*, which involves understanding that all forms of disciplinary knowledge are points of view shaped by particular combinations of language and representations under certain social, historical, and political influences. In this way, critical framing helps students interpret the social and cultural context of different texts and constructively critique them. This aspect of critical framing is perhaps the most distinctive in my conceptualization of a third space as compared to other studies reviewed below. How a third space is operationalized in classroom practice will be further discussed in chapter 3. Eventually, critical framing allows students to creatively extend the texts to produce new ones in new contexts, and this is the end goal of *transformed practice*.

Although multiliteracies provides a useful pedagogical principle at a broad conceptual level, empirical research using this framework tend to focus on English language literacy in light of the increasing use of multimedia technology in contemporary society. The lack of specific examples in content-area literacy, especially in science, is a potential gap to be explored. This is where I turn to several empirical studies in third space that focus on science learning.

Third Space Studies in Science

Empirical work in creating a third space for science learning, especially at a high school level, is extremely rare. As Moje (2007, pp. 29-30) notes, "the majority of the work [in third space] has been done in secondary English language arts and social studies… very little work has been developed in upper-level science or mathematics." To date, only a few studies have explored youths' funds of knowledge as literacy resources for a science curricular unit (e.g., A. C. Barton & Tan, 2009; Buxton, 2006; Moje, et al., 2004).

One exemplar in elementary school is Barton and Tan's (2009) three-year design-based research to adapt curricular and pedagogical practices in linking canonical science with sixth graders' literacy practices in a low-income urban school. Working with classroom teachers, they found numerous types of cultural knowledge and experiences from students that could be used in a specifically designed instructional unit. For instance, in a lesson on food nutrition, the students' frequent visits to and knowledge about fast food restaurants came in handy in a later instructional task about healthy meals. Barton and Tan concluded that the students were active creators of a hybrid third space partly due to the refined curriculum's active invitation to use their out-of-school resources. Their findings suggest that the obstacle in generating a hybrid space does not arise so much from the different cultural practices themselves, but lies with the degree of willingness of the teacher and affordances of the planned curriculum in firstly, allowing non-school related cultural practices to be counted as legitimate in classroom discourse, and secondly, scaffolding these practices toward the kind of literacy practices required in science learning.

A second exemplar comes from Moje and colleagues (Moje, et al., 2004; Moje, Collazo, Carrillo, & Marx, 2001) who examined the literacy and discursive demands of a middle school project-based science curriculum and enactment. Although the literacy practices in the project-based curriculum were generally designed to elicit students' everyday experiences, they found competing demands arising from the differences between the students' literacy practices and the literacy practices of the science classroom. This is because the project-based curricular activities were targeted at the literacy practices of information gathering, dissemination, organization, and presentation, which were not familiar to many students from a non-mainstream background. Furthermore, there was a lack of scaffolding on the teachers' part to integrate the students' community experiences with the literacy practices demanded in the activities in order to create a third space. Through this study, Moje and colleagues note the difficulty and complexity involved in connecting student everyday practices to those demanded in science learning.

It is telling that studies focusing on elementary science (e.g., Barton and Tan's study) tended to report more optimism in establishing a third space whereas Moje and colleagues' work (2004) in middle schools noted considerably more difficulty in "making sustained connections from youth everyday knowledge to advanced science subject matter learning and text practices in classrooms" (Moje, 2007, p. 31). This signals an increasing divergence between everyday and science discourses at higher grade levels. This divergence becomes even more prominent in high school when general science is branched into various specific disciplines of physics, chemistry, biology, and earth science, each with a unique and highly-specialized discourse. This is perhaps why few studies in third space creation have been carried out in a high school science classroom.

Another interesting study is the work by Brown and Kloser (2009) in understanding how a group of ethnically-diverse baseball players talked about the trajectories of curveballs. Although Brown and Kloser did not situate their work in an instructional setting, their findings are relevant due to the connection between baseball and physics that also appeared in my data. Through their interviews with 15 players, they reported that the "discourse of baseball, much like that of science, includes complex conceptual, symbolic, and linguistic features" (p.291), and can be useful in supporting student learning in physics. However, their lack of data of students learning school physics through the bridging of baseball discourse hinders the understanding of how such bridging (if there was any) actually occurred. Furthermore, as Yeo (2009) critiqued, Brown and Kloser underestimated how the thematic patterns (Lemke, 1990) of baseball lexicon are widely different from those of physics lexicon, and may therefore cause more hindrance to students' conceptual understanding.

As I will show in chapter 5, my findings in the connection between physics and sports (I use colorguard as an example) support some of the claims made by both Brown and Kloser (2009) and Yeo (2009). First, sports discourse does involve complex semantic features and relationships that mirror the complexity of those used in science. Second, the lexicons from both discourses are widely different and cannot be mutually substitutable even when they are using the same words (e.g., force, lift). However, I will also show that both Brown and Kloser and Yeo, by standing on both sides of the aisle, fail to consider the possibility of *voice appropriation* and *hybridization*. These central theoretical notions, which provide the foundation of chapters 6 and 7, will be further reviewed in the next section.

Hybridity and Space

In this section, I review theories that help me expand the meaning of the term "hybrid third space" word by word. That is, what is hybridity? What is a third? And what is a space? This theorization is important in distinguishing my work from other researchers' interpretations of a hybrid third space. As it is almost impossible to summarize the intellectual works of Homi Bhabha, Mikhail Bakhtin, and Bruno Latour in a short section, I will only highlight several insights that are relevant to my work.

In-between Space – Bhabha's Hybridity

The notion of *third space* is most associated with Bhabha's (1994) post-colonial work in cultural diversity and differences. In his analysis of culture and identity during colonialism, he observes that while the colonizer sought to impose an essentialist discourse to shape the identity of the colonized (the Other) to become one of itself, it ended up producing something new and unrecognizable to both the colonizer and colonized. Thus, he proposes the construction of a political hybridized subject that is "neither One nor the Other but something else besides, in-between" (p.219). In this way, Bhabha breaks down the dichotomy between self and otherness and the separation of cultures between the colonizer and the colonized. Instead, through a post-structuralist notion of difference, he stresses the interdependence between the colonizer and colonized, and introduces the concept of *hybridity* as the creation of new cultural forms from the encounters produced by colonization. This process of cultural hybridity is an in-betweeness through the straddling and negotiation of two cultures, and always gives rise to something new, different, and unrecognizable.

Bhabha's hybridity of cultures steers post-colonial studies away from cultural polarity and binarism, and gives sense to the notion of a "third space" that is neither Ourselves or the Others. It is important to note that Bhabha is often misunderstood for advocating a third in contrast to the existence and dichotomization of a "first" and "second." Instead, for Bhabha, "the importance of hybridity is not to be able to trace two original moments from which the third emerges, rather hybridity is the 'Third Space', which enables other positions to emerge" (Rutherford, 1990, p. 211).

Recontextualizing in educational setting, Bhabha's third space is often analogously used to draw contrast with the imposition of a hegemonic disciplinary discourse like science (the colonizer) on the students' discourses (the colonized). Instead of seeing it as a conflicting imposition, Bhabha's insight provides a dynamic way of describing new possible spaces, and diffuses the existing boundaries and categorizations of established discourses and identities. This provides a useful way of seeing new possibilities, rather than liabilities, emerging from the interaction of multiple discourses in the classroom. However, the lack of detailed discursive analysis in Bhabha's broad framework hinders its application in classroom discourse. This is where I turn to Bakhtin's intertextuality as a discursive lens for examining hybridity and Latour's actor-network theory for deconstructing what researchers mean by the term "space."

Hybridizing Voices – Bakhtin's Intertextuality

Intertextuality, or the juxtaposition and linkage of texts, is an important area of research based on the theorization of Bakhtin (Lemke, 1992). Its basic notion is that a text is never an isolated piece of work, but it always explicitly or implicitly incorporates, assimilates, echoes, challenges, parodies, or responds to prior texts as well as anticipates future texts in "chains of speech communication" (Bakhtin, 1996, p.94). According to Fairclough's (and other social semioticians') interpretation, there are two basic types of intertextuality. The first type is called *manifest intertextuality*, "where specific other texts are *overtly* drawn upon within a text" (Fairclough, 1992, p.85), such as citing or importing a quotation from an actual source. The second type is called *constitutive intertextuality* that involves the deployment of less visible elements of discourse that cannot be easily traced to direct sources, but are implicitly drawn upon during a text's production and interpretation. In my work, the most important element drawn upon is that of "voice."

A *voice* is an ideological stance toward a discourse that is populated within an utterance. For Bakhtin, no utterance is completely unique and ideologically-neutral. People borrow and adapt others' utterances and voices in order to construct their own. Through such appropriation of others' voices, any utterance is always "a packet of discourse replete with an ideology" (Kamberelis & Scott, 1992, p. 211). This thus gives rise to what Bakhtin called *heteroglossia*, or the existence of speech diversity within a text or speech conversation. This Bakhtinian notion of voice is useful because it rejects the autonomy of a unitary author or text in the construction of utterances, and instead traces the mosaic of other people's languages borrowed and transformed by an author. An example of its usefulness will be illustrated in chapter 4 and 5 where I traced the voices of a conservative religious community speaking through Naomi, whose utterances I had briefly introduced in the first chapter.

Furthermore, the notion of voice is also important for Bakhtin's (1981, p.358) work in *hybridization*, which he defined as "a mixture of two social languages within the limits of a single utterance… between two different linguistic consciousnesses, separated from one another by an epoch, by social differentiation, or by some other factor." Because of voice appropriation, "all our utterances are filled with others' words [with] varying degree of *otherness* or varying degrees of '*our-own-ness*'" (Bakhtin, 1986, p.89, *italics* added). In this sense, there is a resemblance with Bhabha in that hybridization is not fully ourselves and the other, but a new utterance filled with varying degree, or an in-betweeness, of the two. Bakhtin's notion of hybridization played an indispensable role in how I saw the process of hybridization in my data, and will be extensively illustrated in chapter 6. In that chapter, I will also provide specific examples from a dialogue between two students in colorguard and myself to illustrate what Bakhtin meant by the varying in-betweeness of "two different linguistic consciousnesses" separated by the discourses of colorguard and school physics.

Spatializing Space – Latour's Actor-Network Theory

Finally, I move on to deconstruct the notion of "space", a concept that is seldom articulated by researchers using the term "third space." The conceptualization of social spaces is a new and exciting area of research in what Vadeboncoeur et al. (2006) call the "spatial turn" – an obvious intertextual reference to the various "turns" that have taken place in social science research, such as the cognitive, linguistic, and multimodal turns in the 1960s, 1970s, and 1990s respectively. One of the most crucial ideas of this spatial turn is to move away from the essentialist metaphor of space as "abstract containers" toward seeing space as a socio-technical network inhabited by material trajectories and circulation of concrete objects, like texts and people.

An important contributor to this network view of space comes from Latour's actor-network theory. Latour sees social science research as being plagued by the artificial dichotomization of space and time, micro and macro, and local and global. He thus advocates the need in "localizing the global and redistributing the local." (Latour, 2005). To Latour, all "global" entities (e.g., economy, culture, science) do not exist as a priori social structures, but are merely cumulated manifestations of local interactions of humans and non-humans in a bounded space and time (or simply space-time). Moreover, such local space-time interactions are always distributed and interconnected to other space-time interactions in complex ways. As such, space itself is the product of humans and non-humans interactions composed through multiple enactments, rather than a static and independent frame which interactions simply occupy.

Influenced by Latour's views, literacy scholars such as Nespor (1994, 1997) and Leander and Lovvorn (2006) have further articulated the concept of space as applied in school ethnographic research. By seeing school as an "array of intersections", Nespor (1997, p. xiii) argues that one should not examine learning or schooling as occurring *inside* classrooms or schools, "but in relations that bind them to networks of practice extending beyond." This is shared by Leander and Lovvorn (2006) who coined the term *literacy network* as a way of reconceiving adolescents' literacy practices and identities through a distributed network of space-time interactions involving other people and an array of mobile elements, such as textbooks, classroom worksheets, computers, video game interfaces, and virtual avatars.

By spatializing "space as container" into a network of circulation and intersections, it becomes possible to analyze learning and hybridization in a third space not as a union or overlap of dichotomous discourses in an abstract sense, but as traversals (Lemke, 2002b) of students and mobile elements (e.g., texts) crisscrossing each other across space-time interactions in complicated ways. This will be further elaborated in my theoretical/methodological framework at the beginning of chapter 3.

Chapter 3

Methodology in Researching Third Space

In this chapter, I discuss the theoretical and methodological framework that guides how I conceptualize and conduct this research study. I then elaborate the use of design-based research methods and the curricular enactment of Text-Synergy. This is followed by a description of the sampling procedures, research setting, participants, role of researcher, data sources, and data analytical methods. I also address the validity of this study at the end of this chapter.

Theoretical and Methodological Framework

Following up on the theoretical review of hybridity and space from the previous chapter, I begin by outlining a framework that guides the way I conceptualize the research design and collect and analyze my data. As a contrasting example to my approach, I start by describing a very common model of researching third space. This "container model" is visually represented in Figure 2.

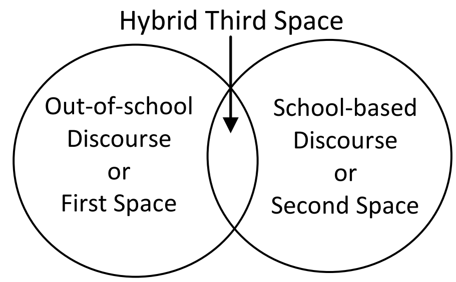

Figure 2. A common conceptualization of hybrid third space.

The container model brings many limitations to researching third space. First, it gives a static view of literacy and knowledge existing within clearly defined boundaries of discourses, and inaccurately portrays a third space as simply an overlap of the literacy and knowledge in each discourse. Second, it implies an a priori and natural existence of a third space independent of any human role and effort to forge one. In other words, the researcher simply has to "find" this third space instead of making one happen in the classroom. Third, it obscures the roles of texts, people, and material objects, and the relations that bind them together in practice. Fourth, it does not give a sense of time and location of when, where, and how hybridization occurs and progresses. Lastly, it masks the possibility for a discursive analysis of hybridization.

Informed by my reading of Latour (see previous chapter), I conceive a more useful network model for researching third space. A simplified visual representation of such a model is shown in Figure 3. It is a simplified version because of the impossibility of showing the sheer complexity of a huge, transient, and ever expanding network. Latour's actor-network is not a static network like a social networking site or a sewer pipeline network. Instead it is a transient and dynamically-shifting *network of* *interactions* that changes in every instance of time. Nonetheless, I show a snapshot of a small network for the heuristic purpose of my explanation.

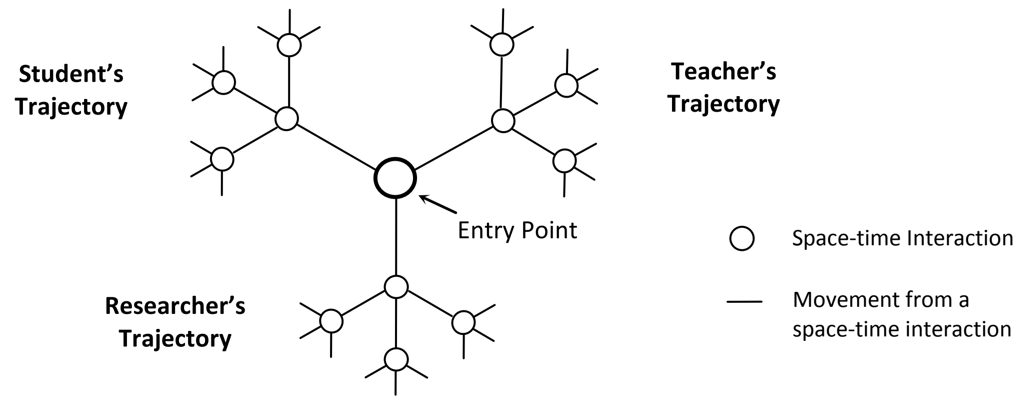

Figure 3. A network conceptualization of a hybrid third space.

Figure 3 shows a network trajectory, with each circle representing an interaction among humans and non-humans in a particular space-time event, such as a researcher sending an email or a student reading a book on a certain day at a certain place. The line between the circles represents a physical movement of a human or non-human from one interaction to another interaction of another time and location; for example, the email reaching the teacher's computer or the student going into the teacher's office after reading the book. In Figure 3, I have also organized the network trajectory into three clusters of network (in reality, they are much messier), with each cluster representing a student's, teacher's, and researcher's trajectory. Each clustering characterizes a person's "life trajectory" through the histories of people, things, activities, places, and events that connect to this person. Besides going back in time in showing a person's historical life trajectory, Figure 3 can also be read as moving forward into the future as the new trajectory of interactions that are continually being forged in time for any person.

A student's and teacher's trajectory can intersect each other in multiple ways, and in the process mutually shape and are shaped by each other's trajectory. The most common intersection is a face-to-face interaction in the classroom. However, their trajectories can also intersect through other ways, such as the student reading a textbook chapter assigned by the teacher or the teacher grading a student's work. As for the researcher, studying the network of a classroom means that the researcher needs to position himself into the student-teacher network and become part of it. This requires the researcher to create what Nespor (1997) calls an "entry point" and project his network trajectory into the student's and teacher's trajectories. The most obvious entry point is when the researcher contacts the teacher for the research project and subsequently goes into the classroom for daily observation.

More importantly, in forging a third space, the researcher has to create an entry point that could shape the configuration of the network into one that approaches a third space. In this research, this was carried out through the use of a *choice text*, where each student picked a text from his/her life trajectory that had relevance to what he/she would later learn in class. The notion of a choice text will be further elaborated in the research design, but for now, I will elaborate how the creation of an entry point was carried out in relation to the goals of the research.

The goals of this research can be broadly divided into three aspects: critical ethnography, curricular transformation, and theory building. Each of these aspects is associated with each cluster of network – the student's, teacher's, and researcher's trajectory respectively, as shown in Figure 4. As represented by the arrows in the diagram, each of these goals can be seen as a network-building trajectory in each cluster.

I begin by explaining the critical ethnographic goal, which was to study the students' funds of knowledge relevant for science learning. Through a student's choice text as an entry point, the researcher gained access into the student's trajectory through interview questioning and textual analysis. This was carried out through Latour's principle of "following the actor", which traced and mapped out the student's literacy practices in relation to their choice text[1]. For example, using the choice text as a context for the interview, the researcher asked and learned more about a student's past and present activities and experiences. Through that, the researcher assembled a network of texts, statements, interview excerpts, and student quotations in order to make an inference of that student's funds of knowledge. This approach and the findings will be further presented in chapters 4 and 5.

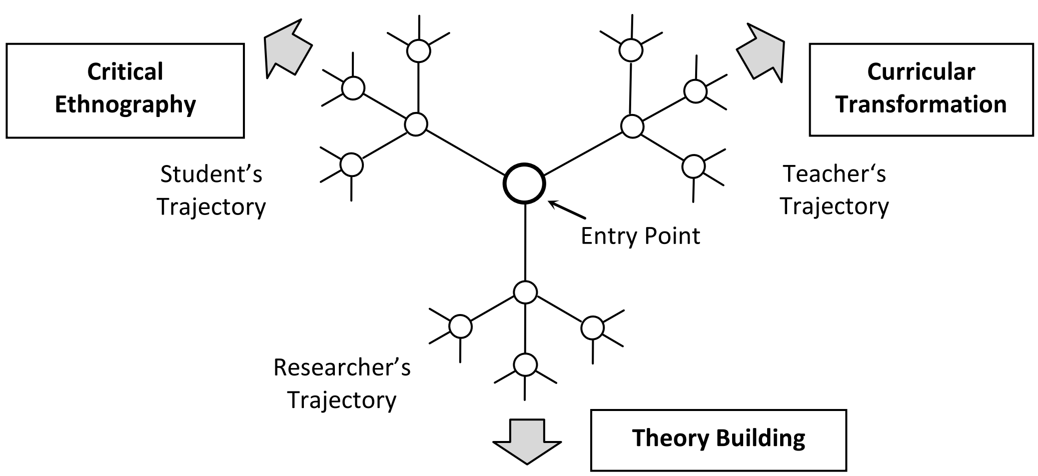

Figure 4. Three different aspects of research study through the network.

[1] Literally speaking, the researcher does not travel back in time to trace a student's historical trajectory, but relies on the student's narrated textualization of his/her life history through the interview. In this sense, the interview session should not be seen as a timeless window into someone's past, but as a space-time interaction in which the researcher and the student are co-constructing a trajectory that is moving forward in time.

In curricular transformation, the emphasis shifted from the students' trajectory to the teacher-instructional trajectory. Unlike the critical ethnographic aspect used to map out the students' past trajectory, curricular transformation involved an active configuration of the network to change the classroom environment in order to create the conditions for a third space to evolve. In this aspect, the choice text served as an entry point for a student to connect his/her life trajectory to a learning trajectory that Text-Synergy envisioned. This is where I conceive the occurrence of hybridization; not as an overlap of two discourses (depicted in Figure 2), but as connecting one's past trajectories with another's to create a new kind of network configuration. Exactly how this hybridization process occurs remains unknown to researchers, and is therefore an important question to be addressed in this study. In particular, chapter 6 is devoted to understanding this process, while chapter 7 examines the extent of such hybridization in Text-Synergy.

Finally, in theory building, the goal is to contribute to theories in the educational research community through the researcher's practical involvement in the student-teacher network. In this aspect, the researcher made new connections between the student-teacher network and what had been said in his research community. Figure 4 is particularly appropriate in representing this theory-building process, because as Latour and Woolgar (1979) showed through their study of a microbiology research center, scientists build their theories through a complex network assemblage of utterances, statements, inscriptions, research papers, microbes, chemicals, lab rats, and machines. In other words, theory-building *is* network building. Thus, the writing of this dissertation, which puts together a corpus of interview excerpts, video records, artifacts, analyses, and citations of other researcher’s publications, is part of this network building. When this dissertation is published, it also becomes a connecting node for the ever expanding network trajectory in the research community.

There are several useful benefits of this network conceptualization compared to the container model. First, it deconstructs an abstract “space” to show the concrete circulations of texts and people anchored in specific time and place. This not only foregrounds the critical role of texts in human interactions, but also allows me to conceive how hybridization could occur as a result of the movements of texts across students, teacher, and researcher. By anchoring interactions in specific time and place, this allows me to move chronotopically (Bakhtin, 1981) in tracing the students’ life trajectory in chapter 4 and analyzing how those life trajectories played a role in their subsequent hybridization in chapter 6.

Lastly, this network conceptualization also accurately depicts the researcher not as a distant and impartial observer, but as an intrinsic part of the entire network. It also illustrates the mutual relationships between research, practice, and theory, and how they impact each other. Just as the researcher’s theoretical reading within the research community informed his design and implementation of a third space, what was learned from his practical participation within this classroom also informed the theory building work in his research community. In the next section, I will further elaborate the design of this third space and its curricular component.

Design-based Research & Curricular Approach

A third space is not a natural occurrence in most secondary classrooms as students typically learn disciplinary literacy and knowledge decontextualized from their life experiences and interests. As such, the researcher, in collaboration with a classroom teacher, needed to put in place certain pedagogical conditions for a third space to evolve. These conditions eventually developed into a curricular approach, which I called *Multimedia Text-Synergy* (Tang, Tighe, & Moje, 2011). For this dissertation, the primary purpose of Text-Synergy was to create a setting for hybridizing understandings to occur, and render the phenomenon visible for study. In this section, I describe its conceptualization and design aspects, while a later section describes its enactment in the research site.

Rationale for Using Design-based Research Methods

The methodological basis for carrying out a curricular approach (i.e., Text-Synergy) as part of a research study was informed by work in design-based research. Design-based research is a relatively new methodological approach developed by learning scientists (e.g., Bells, 2004, Collins, Joseph, & Bielaczyc, 2004). Recognizing the situated nature of classroom learning (J. S. Brown, et al., 1989), design-based research advocates the importance of situating the research within the messiness of a real-world setting of the classroom as opposed to a laboratory-controlled experimental study. Design-based research also recognizes the dual purpose of refining theory and practice through a progressive refinement process. These characteristics of design-based research are well aligned with my earlier theoretical framework of a network trajectory that posits the integration of a researcher's trajectory into the classroom network trajectory.

I used methods from design-based research to enact and collect data on Text-Synergy. In particular, I studied the process of developing a third space and evaluated its success and limitations as a classroom practice at the same time. Design-based research was particularly essential in addressing the circular cause and consequence problem that I faced in my study. This was because in a typical science classroom, out-of-school texts are rarely brought into the classroom conversation. Hence, to study third space, I first had to construct the conditions necessary for allowing third space to evolve in the context of our study. Yet, constructing the conditions for third space also requires research on how to do so. To address this conundrum, I utilized the iterative cycles of design-based research to simultaneously study Text-Synergy and refine its practical implementation. Design-based research was also useful in breaking down the dichotomous divide between research and practice and ensuring all parties involved (i.e., researcher, teacher, students) benefited from the research.

There is a broad range of theoretical perspectives behind design-based research. Instead of a singular definition, Bell (2004) argues it is more useful to consider "four manifold families" of theoretical framed design-based research. Of these four, my approach is closest to what he calls a linguistic anthropological design, which seeks an emic (insider) orientation to understand the meaning of an intervention and its consequences from the point of view of the participants, instead of emphasizing measurements of its effectiveness through an etic (outsider) orientation. Such an approach aims "to make culturally grounded improvements in specific settings through our interventions once we come to better understand the people and places" (Bell, 2004, p.248), and is increasingly used to actively link ethnography to design, particularly in settings between the social worlds of school and home or school and workplace (e.g., R. R. Stevens, 2000).

Curricular Design of Multimedia Text-Synergy

While design-based research provided the methodology for conceptualizing Text-Synergy as part of my overall research, multiliteracies (see chapter 2) provided the pedagogical framework that informed the curricular design of Text-Synergy. In particular, the critical framing aspect of multiliteracies had the greatest influence over how I designed Text-Synergy. According to the New London Group (1996), critical framing involves the understanding that all forms of disciplinary knowledge are points of view shaped by particular combinations of language and representations under certain social, historical, and political influences. In my view, this is one of the most important features of a third space that was not emphasized in past research. As such, the design of Text-Synergy placed a particular emphasis on this vision of critical framing. In particular, I posited a necessary condition for critical framing to occur is when students are confronted with texts about science, nature, and technology drawn from their out-of-school communities vis-à-vis those in academic science. This was the basis for the key idea of incorporating and integrating a choice text from the students.

The following describes the procedures taken in the development and enactment of Text-Synergy:

1. Each design-based research cycle was organized around a major science unit (e.g., mechanics, electricity, waves). Originally, three cycles were planned, but due to time and scheduling constraints, only two were carried out. The first cycle focused on mechanics, while the second on electricity.
2. A week prior to the start of each unit, each student was asked to select a text (i.e., choice text) he or she had read or was likely to read. While there was no restriction on the media (e.g., article, video, website), the text's content had to be related to both the student's interests and the physics unit that would be taught later. Chapter 4 gives a summary of the nature and frequency distribution of the students' choice texts in both cycles.
3. Each student also posted a written journal to explain why the particular text was chosen, how it related to the physics topic, and what he/she wanted to learn in order to understand the choice text better. An online forum (Moodle) was used to facilitate these journal postings and collate their choice texts (mostly URLs and digital copies).
4. Eight student informants were selected and interviewed (pre-cycle interview) to find out more about their text selection and how they saw the connection between their texts and the physics topic.
5. Based on preliminary textual analyses and student interviews, the teacher and I designed an end-of-cycle assignment (called *text assignment* by the teacher) to guide the students in connecting their choice text with the physics topic. This assignment was also an instrument for assessing the students' conceptual development and critical framing. In the form of a 2 page single-spaced essay, the

assignment had two major requirements. The first required the students to write a scientific explanation of a self-identified phenomenon in the choice text using the language and concepts learned in class. The second requirement was to write a critical evaluation of how science was presented in the choice text compared to the textbook. Chapters 6 and 7 provide more details on these two requirements (explanation and evaluation) respectively.

6. Concurrently, we also designed instructional strategies to harness the resources in the choice texts and address their differences with school-based texts. These strategies were implemented in several lessons throughout each cycle.
7. After the students submitted their text assignments, the same eight student informants were interviewed again (post-cycle interview) to find out what they had learned during the cycle and their views on the appeal and usefulness of Text-Synergy.
8. After the completion of the first cycle on mechanics, minor revisions were made and the above procedures were repeated in the second cycle on electricity.

Selection of Site & Participants

The research site and participants in the classroom where Text-Synergy was implemented were purposefully selected (Patton, 2002). In this section, I elaborate the rationale and process of this selection, beginning with the broadest selection based on age group and subject matter and narrowing it down to specific selections of student interviewees.

Why High School? Why Physics?

The selection of a high school was informed by the literature, which suggests the widest gap between in- and out-of-school discourses exists in upper secondary level. This is due to adolescents' (age 15 to 18) diverse interests and participations on the one hand, and the specialized disciplinary subject matter in high school on the other. As children grow older, they acquire more secondary discourses (Gee, 1990) through their socialization in various communities beyond their family. This provides the context for the researcher to focus on the divergences among multiple secondary discourses with school discourse, rather than the binary between an "everyday" home and school discourse that has characterized past research, especially in elementary school. On the other extreme, college students specializing in a science degree have a strong predisposed interest toward science, while there are still many high school students who find school science unpleasant or difficult. In short, high school adolescents offer the best transitory age for the purpose of this dissertation.

At the same time, high school science presents the greatest divergence from students' lifeworlds. As the subject is further divided into the various disciplines of physics, chemistry, and biology, each of these disciplines has its own unique and highly-specialized discourse and ways of representation (e.g., free-body diagram, Lewis structure). Among them, physics is generally perceived to present the greatest range of phenomena and applications close to our daily life, such as motion, gravity, light, sound, heat, energy, sports, electronics, transportation, flight, and building structures. It also captures some of our wildest fascination and imagination such as time travel, space exploration, and the origin of the universe. Yet paradoxically, nation-wide surveys of youths (Osborne, et al., 2003) have shown that school physics was the least interesting and most difficult science subject. Furthermore, the disparity in male to female ratio was the most unequal in physics at 3.4 : 1. Thus, this paradoxical contrast between the apparent connection to physics and the actual disparity in high school physics presents a fertile ground for investigation in this research. Furthermore, few studies in third space focused on high school science, be it in physics, chemistry, or biology.

Another reason for selecting physics was due to a widespread belief that physics occupies the pinnacle in the so-called “unity of science”; followed by chemistry, biology, other “hard” sciences, and the “soft” social sciences (Harding, 1986). This unity of science paradigm is based on a positivistic ideology that views science as authoritative, impersonal, and objective. Not only is such an ideology pervasive in public opinion, bureaucracy, and schooling, it is also dangerous for a modern democracy as it promotes the self-interest of a technocratic elite (Lemke, 1990, 1995). Therefore, in Vision II of scientific literacy (Roberts, 2007), an important but often neglected goal is to make the general public aware of such ideological use of science. In Text-Synergy, the purpose of critical framing is to facilitate this long term goal. Because physics occupies the pinnacle in this ideology, it is more important to help students see how physics is not about some universal statements and formulae about the laws of nature, but is a creative enterprise deeply tied to human activities in specific historical and socio-political contexts.

Selection of Teacher(s), Class, and Student Informants[2]

The selection of a research site was first based on recommendations of effective high school physics teachers who might be suitable for the project. The choice of an effective teacher was essential as a certain level of experience, commitment, and cooperation was required. Among several candidates who expressed interest after an invitation, Brad was selected because of his passion for exploring the use of literacy in physics teaching and connecting with students' out-of-school literacy practices. This criterion was informed by Barton and Tan's (2009) finding that the success in generating a third space depended on the degree of willingness of the teacher more than any other variables.

Besides Brad who became my main collaborator, there was also another physics teacher from the same school, Kathryn, who was partially involved in the research. Brad and Kathryn closely shared their teaching materials and resources. Both teachers had expressed interest in participating in the project, but only one classroom was observed due to the time constraint on my part. Nevertheless, even though Text-Synergy was not implemented in Kathryn's class, she was informally involved through many sharing and dialogue sessions. Furthermore, Kathryn also allowed surveys (see later section) to be administered in her classes. As Brad and Kathryn had one honors physics class each, Kathryn's class was designated as a non-intervention control group in the survey in comparison to Brad's selected class.

At the time of research, Brad taught two classes of AP (Advanced Placement) physics and one honors physics, while Kathryn had one honors physics and two

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[2] Pseudonyms were used for all people and places directly connected to this study.

conceptual physics classes. The decision to select honors physics was unanimous among the three of us as that was a common class for both teachers. Furthermore, because AP Physics was designed specifically for students who were extremely interested and academically strong in physics, they might not fit well with the research focus in studying a third space. On the other hand, there was a diverse range of students with varying ability and interest in honors physics, and such diversity was useful for an exploratory research.

Every student in Brad's selected honors class (N=33) was recruited as a participant in the research, and all students (including their parents) gave permission to be included in the classroom videotaping and for their work to be collected. With the exception of four students, everyone also gave permission to be interviewed. From these 29 students, I then narrowed a selection of eight students as key informants for interviews. This narrower selection allowed me to interact with and focus on a manageable group of students more intensively throughout the entire course. For this selection, I used a maximum variation sampling strategy with criteria based on a variation in: (1) gender, (2) science test scores, (3) students' interests and hobbies, and (4) interesting choice texts submitted. My original sampling included one of two minority students in the class. However, because both of them were among the four students who declined to be interviewed, all eight student informants were from the same ethnic group.

Description of Setting & Participants

The School & Community

Victoria High School was the only public high school in the school district of a suburban community located at the fringe of a metropolitan area in the midwestern United States. At the time of the 2000 census, the community had a population of 33,463 and a median household income of $71,844. 92.1% of the adults over 25 were high school graduates, and 36.3% had at least a college degree. The racial composition was predominantly white with a majority of 95.4%. The school offered a broad-based curriculum to an enrollment of approximately 2,560 students in grades 9-12. Opened only about a decade ago, the campus included a gymnasium, natatorium, auditorium, information resource center, computer labs, and automotive and vocational labs. The school considered technology as an integral part of its curriculum, and was named one of the few top schools in the use and implementation of technology in the nation. In addition, it won several exemplary school awards at the state and federal level. During the 2009-2010 school year, the number of faculty was 127 and the graduation rate was 89.1%.

The Teacher

At the time of research, Brad had 11 years of teaching experience, including 7 years of teaching physics. He had been teaching in Victoria High throughout his teaching career. With a Bachelor degree in Education and a Master in Interdisciplinary Science, he taught mostly physics, honors physics, and AP physics. Like most students in Victoria High, Brad is of European descent and is from a middle-class background.

Brad believes strongly in the role of literacy in teaching content area. He defines literacy as the ability in "using information provided to make synthesis and judgment." In an interview, he recalled being influenced by a content area reading professor in college and mentioned it was the most useful thing from college he had applied in his teaching. From this influence and his own teaching experience, Brad described himself as more "text-focused" compared to other physics teachers. During class, he used the textbook often to deliver content. However, Brad did not believe in just teaching from the textbook as he also felt it was important to get students to read critically and "navigate the textbook" on their own. He reasoned that this ability to read from the textbook would be more important for the students in college as they were expected to read more difficult texts more independently.

Complementing his views of literacy instruction, Brad frequently used an assortment of literacy teaching strategies in class. The most common strategy was the use of reading guides to accompany the students' textbook reading. Each reading guide consisted of a series of recall and comprehension questions for the students as they read the textbook. Brad expected his students to prepare themselves for class by completing the reading guide before the start of every new chapter. Halfway through the research, Brad reflected that his reading guides had been asking mostly basic questions, and has since modified some of them to include more difficult questions. Other literacy teaching strategies which he frequently used in class included SQ3R (survey, question, read, recite, review), Bloom's taxonomy questioning, vocabulary review, and summary writing.

Based on my observation and interviews, students considered Brad a likable and approachable teacher. They generally felt comfortable in his class and did not feel afraid to ask questions. This was reinforced by Brad's repeated encouragement to the class that they could raise any question and give open and honest feedback about his teaching and the research. Brad also had good rapport with many of his students.

Brad was very interested in this research when he first heard about it. He acknowledged that today's youths were very media-centric and thus he wanted to know more about their media consumption and knowledge about science outside the school. Throughout the research, Brad was actively involved and played a huge role in conceptualizing and designing many of the strategies used in Text-Synergy, including part of the text assignment. He also sat through about 30% of the student interviews. After the research project was officially over, Brad continued to implement Text-Synergy for his subsequent cohorts of classes.

The Class & Students

Following State requirements, all students in Victoria High had to take a one-hour credit course from (a) biology, (b) chemistry or physics, and (c) an elective science for graduation. Each course took two academic terms, or half a school year, to complete. This research took place in the second half of the school year 2009-2010. Thus, the students involved in this research were in their third and fourth terms.

At Victoria High, a school day was divided into four "hours", with each hour lasting 90 minutes except Wednesday when it was 60 minutes. Brad's honors physics class was on the fourth hour. In the school timetable, the fourth hour included a 20 minutes slot for students to watch the school's live daily newscast. This newscast was produced by students in the school broadcasting club, and featured daily announcements, national and world news, and other school-related programs. Some significant news that became relevant as the students discussed them in class included the Winter Olympics, the Haiti earthquake, the BP oil spill, the volcanic eruption in Iceland, and the FIFA World Cup. Many students generally used this time to finish their homework as they watched or listened to the newscast. I also frequency used this period to conduct formal interviews and informal conversations with students (see later section).

The initial enrollment for Brad's honors physics class was 33 students, with 22 boys and 11 girls. In the fourth term, due to the timetabling schedule, 3 boys had to be transferred to Kathryn's honors physics class in the first hour in exchange for 2 boys from her class to Brad's. Thus, the enrollment in the fourth term dropped to 32. Every student in the class had taken biology during their freshman year (mandatory), and the majority had also taken chemistry or honors chemistry. Most students were sophomores and juniors, and there were four seniors and no freshman. Apart from one African-American female student and one Latina, the rest of the students were Caucasian.

With some exceptions, the students in the class generally showed some interest in the lessons and were good in mathematics, which befitted the typical profile of an honors physics class. The students were also academically motivated and concerned about getting a good grade for the course. As representatives of the class, Table 1 gives a summary of the eight student informants selected to represent the diversity of the interest areas and choice texts in the class (except for Evelyn and Joe who were later additions because I wanted at least two different students with the same interest for comparison purposes). I also include in Appendix A further details of these students' biographies.

Table 1. *Student Informants and their Respective Choice Texts and Interests*

Student	**Grade**	**Topics of Choice Texts / Interests**	
		Cycle 1 (Mechanics)	**Cycle 2 (Electricity)**
Lucy	Senior	Colorguard	Mythbuster
Evelyn	Junior	Colorguard	Wind Energy
Naomi	Sophomore	Cheerleading	Creationism / Human Body
Sabrina	Junior	Soccer	Thunderstorm
Hank	Sophomore	Cars	Electric Tram
Benjamin	Junior	Football, Baseball	Hybrid Car
Zac	Junior	BMX	PlayStation 3 Device
Joe	Sophomore	Football	Solar Energy

The Researcher

As I argued in my network conceptualization, the researcher is an intrinsic part of the research and its network, and has to insert his network trajectory into the classroom through the creation of "entry points." One method was to become a participant-observer in this study. Thus, I assumed multiple roles and interacted with the participants in various ways. During regular meetings and debriefs with Brad, I worked as a collaborator in designing and evaluating the lessons. To the students, even though they knew I was a doctoral student doing research in their class, I was introduced to them as a co-teacher on the first day. My role as a co-teacher was also reinforced by the frequent questions and assistance they asked from me during class. Thus, besides observing and taking field notes as an observer, I was also an integral participant when I frequently guided and talked to the students during their individual work, small-group discussion, and laboratory work. Beyond the classroom, I also attended several formal and informal school events, such as a teacher-parent conference and lunch with science teachers.

My role as a participant-observer was shaped by my own experiences and identities, as well as the identities that the participants constructed of me. Before this study, I was a high school physics teacher and a teacher educator in Singapore. I had also been educated in Singapore (K-12), England (college and master in physics), and the U.S. (current doctorate). Thus, my identity as a Singaporean of Chinese ethnicity, my teaching experiences, and my cross-cultural experiences played a significant role in my participant-observation, and data collection and analysis. Not only did it shape how I interpreted the events in the classroom, it also affected how the participants saw me and reflexively constructed our mutual identities and relationships.

Instead of being a liability, my non-American background was an asset in some ways because I was less likely to take for granted what might seem like an ordinary event or common language to members of the same culture. This enabled me to “make the familiar strange”, which is an important principle of school ethnography (F. Erickson, 1984). A good example was the way I made sense of the students’ description of popular sports that are not common outside the U.S., such as American football, baseball, colorguard, and cheerleading. Thus, I kept prompting the students to explain what certain words and phrases meant as they often assumed and expected that I would know them. Through such heteroglossic dialogue, it made me more sensitive toward the different discourses, and was perhaps a major influence that shaped my assertions about discourse conflicts and hybridization in chapters 5 and 6.

In relation to the students' out-of-school interests and background to be shown in chapter 4, I will make explicit my own interests and background. I see sports as purely a physical and recreational activity and was never a sports fan or follower of any match or team. I enjoy water sports like sailing, boating, and scuba diving, play some tennis and table tennis, jog and cycle occasionally, but I am mostly indifferent to other sports. Although I like cars, I do not consider myself a car enthusiast. Despite having a physics degree, I do not know much about the parts of a car and how to fix it. Occasionally, I read the news and blogs to update myself on the latest developments and achievements in science and technology. However, during my childhood, I was never really any kind of a science "geek" in terms of watching science documentaries regularly or knowing the name of every dinosaur.

My passion for science (particularly physics) only blossomed when I studied physics at a prestigious university that housed past and present distinctive scientists like Isaac Newton, Charles Darwin, Ernest Rutherford, and Stephen Hawking. I was particularly interested in theoretical and mathematical physics, and thus opted for more courses in these fields over experimental physics for my undergraduate and master degree. Outside the degree program, I also read widely about the history and philosophy of science, especially on metaphysics and epistemology.

As for my religious views, I was raised as a free-thinker, but shortly after high school in Singapore, I converted to Christianity (non-denominational Protestant) due to a personal incident. Although I currently attend church in the U.S., I do not affiliate myself with the Moral Majority or Christian Right movement. My political views are moderate (according to America's political spectrum), and I firmly believe in the separation of church and state. I believe that evolution and creationism are intellectually compatible. According to a creationist book from Naomi's reading list, I recently learned that my views are called "day-age creationism." I do not think that intelligent design should be claimed as a science or be taught in schools. However, I do agree with Naomi's argument shown in the introductory chapter that science needs to be more honest and modest about its epistemological claims and the role of humans in making those claims, and not be taught, in the words of Naomi, "like fact." I personally think that this is the root of the intellectual conflict between science and all other worldviews, including religion.

The Curriculum & Integration of Text-Synergy

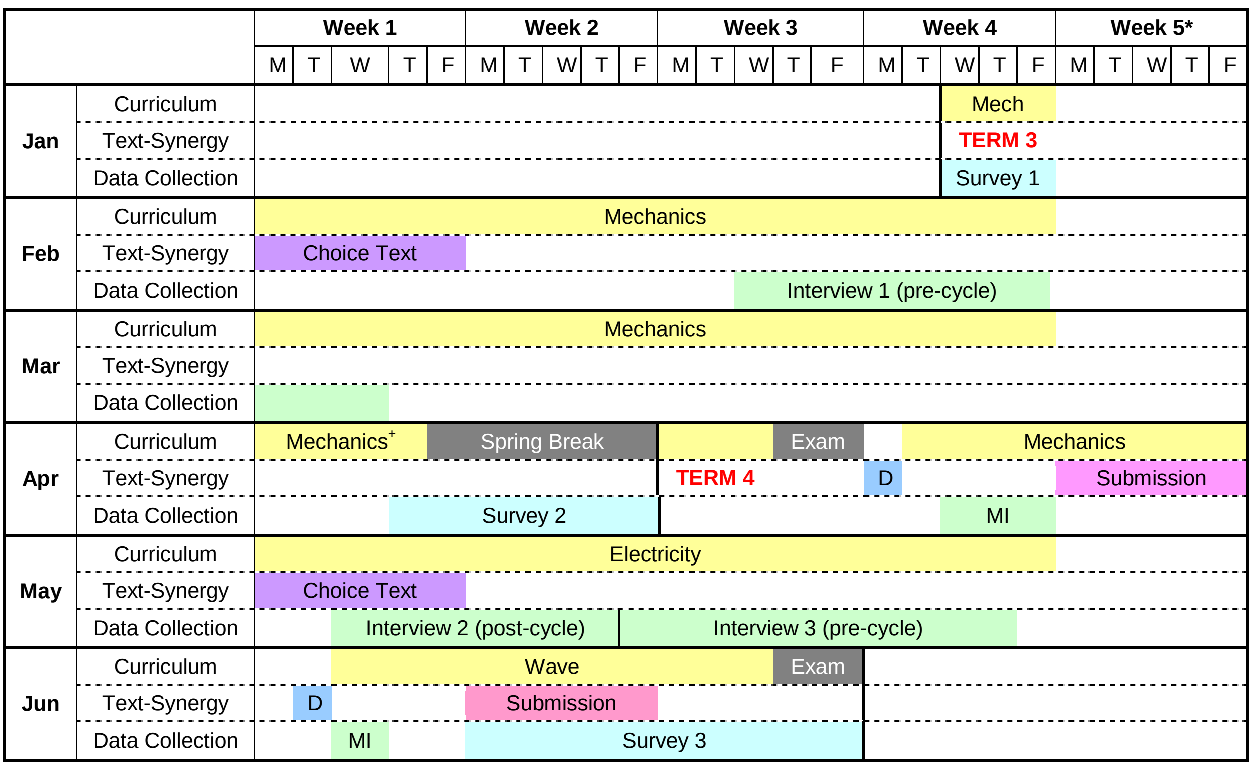
The curriculum for the honors physics class was based on and mandated by the State's high school science content standards. The standards included three main content areas of physics: classic mechanics, electricity, and waves. Classic Mechanics is the most common and foundational unit typically taught at the beginning of a physics course. It studies the non-relativistic motion of macroscopic objects under a set of universal laws, most notably Newton's laws of motion, and it covers concepts like acceleration, free fall, momentum, collision, projectile, and potential and kinetic energy. Mechanics occupied by far the lion share of the curriculum – about 3 months or 60% of the course.

The second content area was electricity, which dealt with static electric charges, direct current, simple circuits, and electrical energy. It occupied one month or about 20% of the course. Lastly, the content area in waves dealt with the properties of vibration and wave-like entities such as light and sound. This content was rushed through during the last two weeks of the course. Magnetism, thermodynamic, radioactivity, relativity, and quantum physics were common topics not covered in the honors physics curriculum. (For the complete curriculum expectation, see Michigan Department of Education, 2007)

The textbook used in the class was Physics: Principles and Problems (Zitzewitz et al., 2005) published by Glencoe Science. This textbook was selected by Brad five years ago and he had been using it for all his honors physics classes. Kathryn also used this textbook for her honors physics class. See Appendix B for a list of chapters in this textbook. In general, there was alignment in terms of the content among the curriculum standards, the textbook, and the students' choice texts. However, there were several prominent areas in the choice texts which were beyond the curriculum standards, such as rotational motion, space-time curvature, alternating current, and radiation.

As Text-Synergy was implemented, there was neither reduction nor change in the content standards, and students in Brad's class took the same standardized examinations as the students in Kathryn's honors physics class. However, we made many changes in the instructional approach and daily lesson plans in order to integrate Text-Synergy in the curriculum as much as time constraint allowed. Some notable integration strategies included: (a) using a student's text about Usain Bolt's 100 meters race to reinforce a recently learned concept about acceleration, (b) using a cheerleading photograph from Naomi to teach Newton's action-reaction pair, (c) evaluating the representations used in a *Mythbuster* episode to teach projectile motion. On a more spontaneous basis, Brad also made frequent and regular references to the students' choice texts and text assignments during a typical teaching day.

The chronological sequence of the curriculum in conjunction with the various stages of Text-Synergy and data collection is shown in Figure 5. As the sequence shows, the first cycle began with the incorporation of choice text on the first week of February and ended on the last week of April when the text assignments were submitted. This coincided with the teaching of mechanics which lasted from the start of the third term in late January to April. The second cycle of electricity began in May and the second text assignment was submitted in June, just a week before the end of term examination. In Figure 5, I also indicated two full lessons where the students discussed their text assignments in small groups. These were activities planned to help the students write their essays before the submission deadline. These are marked as “D” in mid-April and early-June in Figure 5.



Legend: D – Discussion on text assignment
MI – Mentoring interview

+Mar 29-31 and Apr 1-2 is considered 1st week of April
*Only April has a 5th working week

Figure 5. Chronological sequences of the curriculum, Text-Synergy, and data collection.

Figure 5 also indicates the various data collection instruments (besides daily classroom observations) used at different times throughout the course. These collection procedures and the nature of various data sources will be elaborated in the next section.

Data Sources

Qualitative and quantitative data were collected throughout the honors physics course. Qualitative data consisted of interviews, textual artifacts, and videotaped observations and field notes of classroom discourse, while quantitative data consisted of surveys and test-scores.

Interviews

Student Informants. For each cycle, there were pre- and post-cycle interviews for each of the eight student informants. Every interview followed a standard protocol (see Appendix C) customized according to the individual student's identified interests, choice text, and other incidents observed during class. The pre-cycle interview focused on the student's out-of-school activities and literacy practices that were related to their choice text. I also assessed how much they understood their text and its connection with physics. The post-cycle interview focused on the student's submitted text assignment; how they went about completing the assignment and what they learned from it. I also asked about their impressions of Text-Synergy and the physics lessons in general. All interviews were videotaped so as to capture the visual cues and gestures which occurred frequently in the conversation.

Every student informant was formally interviewed three times, except Evelyn who missed the first interview. A fourth interview (second post-cycle interview) was planned but could not be carried out. This was because the text assignment submission was near the end of the course, which was too close to their final examinations (see Figure 5 for the scheduling). Each interview lasted at least 20 minutes, with the longest being about an hour for some students (e.g., Naomi, Zac) who did not mind staying back longer on some days. About half of the interviews were conducted after the school day, which was immediately after the fourth-hour. These interviews were held inside the classroom, and Brad joined these sessions most of the time. The other half was conducted during the 20 minutes of school daily broadcast at the start of the fourth-hour. These sessions were held in private rooms inside the library.

*Informal interview*s. Besides formal interviews with key informants, I also had informal interviews or conversations with every student in the class throughout the course. Most of these interviews occurred during the school daily broadcast when I walked around to talk to various students. Some of these conversations were planned in advance when I wanted to ask specific questions of certain students. Others were initiated by the students, especially those who required assistance in their homework or wanted me to explain some difficult concepts. As I carried an audio recorder with me, about 15 of these conversations were recorded, and their durations ranged from one to ten minutes. However, due to the spontaneous nature of these conversations, many of them could not be recorded. In this case, they were remembered as "headnotes" and subsequently translated to field notes after the conversation.

Mentoring interviews. These were special interview sessions where Brad or I discussed with and mentored some students on the text assignment, particularly near the submission deadline. The nature of these interviews varied across different circumstances. Some were purposefully planned in advance with the students' consent to stay behind after class. These interviews were conducted with Lucy, Evelyn, Joe, Edmund, and Naomi. They were videotaped and each lasted about half an hour. Other interviews were more spontaneous as the students voluntarily asked for help from Brad or myself during and after class. Eight of these sessions were audiotaped. The days when these mentoring interviews took place are marked as "MI" in Figure 5.

Teacher interviews and meetings. I conducted three semi-structured interviews with Brad before the course, during the spring break, and after the course. The interview questions included his teaching style and experiences; views about literacy, science, and science education; evaluations of strategies used in Text-Synergy; changes due to Text-Synergy; and challenges in implementing Text-Synergy (see Appendix D for specific questions). Each interview lasted on average one and a half hours. In addition, I also recorded all our regular meetings and after-class discussions throughout the course (about 20). All these interactions were audiotaped.

Textual Artifacts

Choice Texts. There were two sets of choice texts collected from the two cycles of mechanics (N=33) and electricity (N=30). These texts varied widely according to the different media. Digital copies and URLs were posted on Moodle while printed copies were physically collected. For each choice text, students also posted a written journal on

Moodle to explain their selection and how they saw the connection between the text and the physics topic.

Text Assignments. Corresponding to each choice text collected at the beginning of a cycle was a written essay submitted at the end of the cycle. Both soft and hard copies were submitted. Due to the transfer of students halfway through the course and one senior opting out in the fourth term, the number collected was 30 and 29 in the first and second cycle respectively. In addition, a week before the submission, each student wrote an outline of his/her plan for the essay.

Curricular artifacts and Tests. These included teacher-prepared worksheets such as reading guides, study guides, chapter assessments, chapter tests, and selected students' homework assignments. Digital photographs of these texts were captured with a high resolution digital camera. These artifacts were not meant to be analyzed in depth, but served as secondary data sources to support my analysis of the students' learning development when the need arose.

Participant-Observation

Classroom videos and field notes. Every lesson in the class was observed daily, except on test days, which occurred about every six to eight days. Thus, there were seventy classroom observations and about 100 hours of video in total. A hard-drive digital video camera with a wide angle lens was mounted at the back of the classroom to capture the classroom interaction. At the same time, I wrote field notes to document the events (what they were doing) and modes of participation (how the activity took place) as they occurred. In particular, I paid attention to the kind of literacy instructions that were specific to the learning of physics, for example, learning new vocabularies, using a vector diagram, or reading a velocity-time graph. At the end of every observation, I compiled and synchronized the field notes with corresponding occurrences in the video using a qualitative software called Atlas.ti. This helped me index each video for quick retrieval and referencing during data analysis. The videos and field notes served as secondary data sources to support my findings from the various primary data.

Surveys and Test-scores

There were altogether three surveys conducted at the beginning, middle, and end of the course (see Figure 5). As described below, there were various purposes for different surveys. Apart from some open-ended questions, all the questions in the surveys used a 5-point Likert Scale. The beginning-of-course survey used printed papers, while the other two were online surveys created using a website called SurveyGizmo. The surveys were not anonymous.

Literacy Profile (N=33). This one-time survey at the beginning of the course was administered to get a quick profile of the students' out-of-school interests and literacy practices. The questions revolved around their average weekly frequencies of (a) doing certain activities (e.g., read, exercise, use Internet, go to religious activities), (b) using certain media (e.g., emails, TVs, video games), and (c) consuming different media genres (e.g., drama, news, sports, documentary, sci-fi). Besides helping me know the background of the students better, the results of this survey were used as contextual references to inform my subsequent observation, sampling, interviews, and analysis.

Text-Synergy Evaluation (N=25). This was also a one-time survey but administered at the end of the course. The purpose was to summatively assess how the students felt about the appeal and usefulness of Text-Synergy as a curricular approach.

Attitudinal Survey (N=33, 33, 25). This survey on student attitudes toward physics and the physics class was administered three different times in order to track any significant change and determine the impact of Text-Synergy over the duration of the course. There were 8 questions repeated in all three surveys. The same surveys were also administrated in Kathryn's honors physics class as a non-intervention control group.

Test Scores. Throughout the course, every student took 11 chapter tests and 2 term examinations. Their test scores were collected through Brad.

Data Analysis

I used a variety of analytical approaches to address multiple issues and problems at different stages of my work. In particular, I used (a) Constant Comparative Analysis (CCA) for the issue raised in chapter 4 on *connecting* to the students' lifeworlds, (b) Discourse Analysis (DA) for chapter 5 and 6 on *contrasting* discourses and *hybridizing* discourses respectively, and (c) Mixed Methods (MM) for chapter 7 on *fostering* critical literacy. In addition, the data sources described above were used variously and complementarily as primary and secondary data sources. Primary sources were data used for the majority of the analysis and interpretation in a particular analytical chapter, while secondary sources were supporting data that provided a general context for understanding the primary data and checking my interpretations. Table 2 shows how the various data sources were used in different analytical approaches and chapters.

Table 2. *Use of Data Sources in Different Analytical Approaches and Chapters*

Data Source (Qualitative / Quantitative)	**Chapter 4** Connecting Lifeworlds **CCA**	**Chapter 5** Contrasting Discourses **DA**	**Chapter 6** Hybridizing Discourses **DA**	**Chapter 7** Fostering Critical Literacy **MM**
Interviews (Qualitative)				
i. Student Informants (Pre)	Primary	Primary		
ii. Student Informants (Post)			Primary	Primary
iii. Informal	Primary			
iv. Mentoring			Primary	
Textual Artifacts (Qualitative)				
i. Choice Texts	Secondary*	Primary	Secondary	Primary*
ii. Text Assignments			Primary	Primary*
iii. Homework & Tests			Secondary	Secondary
Surveys (Quantitative)				
i. Literacy Profile	Secondary			
ii. Evaluation & Attitudinal				Primary
Test Scores (Quantitative)			Secondary	Secondary
Classroom Observations (Qualitative)	Secondary	Secondary	Secondary	Secondary

* Qualitative data that are quantified into quantitative data through a coding rubric.

Constant Comparative Analysis (CCA)

CCA is an inductive method that generates broad patterns and categories through a systematic comparison of specific incidents in the data. Although CCA was originally developed from Glaser and Strauss's (1967) "grounded theory", several researchers (e.g. Moje & O'Brien, 2001; Thomas & James, 2006) who disagree with its positivistic epistemological assumptions have reinvented it in a way that is more aligned with a symbolic interactionist paradigm. For example, Moje and O'Brien (2001, p. 198) assert that they "do not believe that following these steps yields one particular truth about the lives of the people in the study", but rather that the "analyses are an aspect of [their] particular situations and relationships in [the] classroom." Such situated approaches of using CCA instead of an objective "grounded theory" are more aligned with the way I conceive theory building as part of a "network building" connecting the researcher's network trajectory and research community with the network trajectories of the participants (see earlier theoretical framework).

CCA provides useful procedural steps for organizing and categorizing the voluminous data collected, particularly its three stages of coding process: open, axial, and selective coding. It is most appropriately used in chapter 4 where there was a need to systematically examine the students' talk about their out-of-school experiences and literacy practices during the interviews. In the open coding stage, I noted and labeled provisional codes throughout the corpus of interview transcripts, and hypothesized initial connections among them. Several recurring codes that were noted include multiple texts and media, prior experiences, enriching present experiences, getting information, using technology, social identifications, affective identifications, reading/doing with family, and peer influences.

In axial coding, I formulated categories (axis codes) of open codes along with the properties that characterized each category. For example, a superordinate construct called *text-experience reciprocity* was generated to label a pattern I saw regarding the mutual connection between texts and experiences. I then compared the codes and categories to look for overlaps, redundancies, and contradictions, and iteratively organized, collapsed, or expanded them. Finally in selective coding, I determined the relationship between the categories and sub-categories, and revisited the data to check for confirming and disconfirming evidence. Through this process, generalizable assertions about the students' literacy practices around the topics of mechanics and electricity within the samples were generated.

In chapter 4, besides using CCA as the main analytical tool, I also used several discursive techniques from DA to complement the coding process. DA is particularly useful in analyzing how language-in-use among the students reflected and instantiated certain social practices and beliefs. In particular, as chapter 4 will show, pronoun analysis and heteroglossic projection of voices were two useful discursive tools used to analyze the students' direct utterances. In chapters 5 and 6, the dual roles of CCA and DA were reversed; that is, I used CCA as a preliminary method to open code and sort through my corpus of texts, while DA was used as the main analytical tool to go in-depth into the data. This will be elaborated next.

Discourse Analysis (DA)

Although all DA methods are broadly concerned with how language-in-use functions as a form of social practice, there is no single homogeneous approach or framework that guides the conduct of DA. Instead, driven by different contexts and problems, DA researchers have used, combined, and developed various approaches relevant to their unique situations. In my work, there is no exception especially given the unique circumstances that I am dealing with (involving literacy, science, sports, religion, media, and instruction).

The various analytical approaches I used for my DA come from SFL-semantic analysis (e.g., Halliday, 1994; Lemke, 1990), multimodal discourse analysis (e.g., Baldry & Thibault, 2006; Kress & van Leeuwen, 1996), and critical discourse analysis

(Fairclough, 1992; Lemke, 1995). I do not see this combination of approaches as an eclectic mix of unrelated approaches, but as a theoretically-informed integration based on two underlying principles of social semiotics. One, language is one of many semiotic systems of representations, and two, all semiotic systems function as resources in making three kinds of meanings in a social context – presentational, orientational, and organizational (see literature review in chapter 2).

These discourse analytical approaches were used in chapter 5 to examine how and why the students' out-of-school discourses were different from school-based discourses, despite their thematic similarities in content as recognized by the students and teachers. In particular, I used SFL-semantic analysis to examine the "thematic patterns of semantic relationships" (Lemke, 1990) to understand how different experiences and perception of events were textually produced, and Kress and van Leeuwen's (1996) "grammar of visual design" to examine how meanings were made with photographs and moving images. Finally, critical discourse analysis helped me relate intertextually these semiotic designs to larger societal and ideological underpinnings, particularly the conflicts and alliances among different social groups and interests.

In the micro-genetic analysis of chapter 6 that examines the hybridization of two different discourses, these three discourse analytical approaches were similarly used. However, a significant difference is that the context changed from a mainly written and synoptic mode in chapter 5 to a spoken and dynamic mode in chapter 6. Thus, in chapter 6, besides the social semiotic approaches, I also used several discursive techniques and ideas from conversational analysis (Sacks, Schegloff, & Jefferson, 1974) and Goodwin's interactionist participation (2000) to complement my analysis; particularly in analyzing how conversations were opened, closed, and shifted on a contingent and moment-by-moment basis.

Mixed Methods

Mixed methods research entails the collection and analysis of both quantitative and qualitative data, and is increasingly becoming a distinct and accepted "third methodological movement" in educational research (Tashakkori & Teddlie, 2003). While there are many variants of mixed method research, including the most basic kind that *separately* uses both quantitative and qualitative data, Greene (2007, p. 126) advocates the use of an *iterative* design whereby the "results of one method [quantitative or qualitative] are used to inform the development of another." This iterative design encompassed the entire research process of this dissertation, including conceptualization, design, data collection, and analysis. As I have already talked about how quantitative and quantitative data were conceptualized and mixed within the framework of design-based research in an earlier section (for more details, see Tang, 2011a), I will now discuss how I used an iterative mixed method for analysis. This form of analysis was particularly useful in chapter 7, where I analyzed both qualitative and quantitative data of students' written work, interview transcripts, test-scores, and survey responses to evaluate the summative accomplishments and limitations of Text-Synergy.

Qualitative analysis focused on the students' written essays. Informed by my findings in chapter 6, two coding rubrics measuring hybridization and critical evaluation were developed to analyze all the students' essays. These quantified codes were entered into SPSS together with the quantitative data of test-scores and survey responses.

Quantitative analyses such as analysis of variance (ANOVA), t-tests, and correlations were carried out to test the relationships among various key variables. Thus, the quantitative results were used to extend and validate the qualitative findings. At the same time, interesting relationships generated through the quantitative analysis were explained through qualitative textual analysis.

Issues of Validity

In qualitative research, validity generally refers to the credibility and trustworthiness of the inferences generated from data (Eisenhart & Howe, 1992). Throughout this study, I addressed this issue of validity through a variety of methods as suggested by Creswell and Miller (2000). First, I sought convergence of findings among multiple data sources (also known as triangulation). I constantly looked for corroborating evidence from other data sources (e.g., observations, interviews, documents, surveys) and methods (e.g., qualitative, quantitative) to support and warrant my claims. This also include the use of a non-intervention honors physics class as a comparison group for the survey results. As shown in Table 2, the large corpus of data and the various uses of primary and secondary data sources also provide a sound basis for my search for convergence. Furthermore, I also searched for disconfirming evidence (F. Erickson, 1985) to check and revise my emerging patterns and assertions during my analysis.

Second, I was engaged in daily participant-observation of the classroom environment over a prolonged period of time (five months). As Fetterman (1989, p. 46) argues, “working with people day in and day out for long periods of time is what gives ethnographic research its validity and vitality.” The long duration allowed me to build rapport and trusting relationships with students and the teacher so that they were comfortable in disclosing information during our extensive conversations and interviews. Being in the field over time also allowed me to check my interpretations against my ongoing observations.

Third, through my daily participant-observation, I also formed a close collaboration with Brad, who was very much an active co-researcher in the conceptualization and data collection phase of the study. For example, every instructional strategy, measurement tool, student interview question was discussed with Brad. He also took part in 30% of the student interviews. Thus, this built the teacher's view into the study and was another way of enhancing validity (Creswell & Miller, 2000).

Fourth, because of these close relationships and collaboration, I was able to do member checking by asking the students and Brad to comment on my initial interpretations and narrative accounts. With the students, I managed to test some initial observations before the course ended, which later developed into the main assertions for chapters 4 and 5. With Brad, I also shared my preliminary observations and asked for his input. In addition, I invited him to co-write a conference and journal paper to present the evaluative findings of Text-Synergy (Tang, Tighe, and Moje, 2011). Thus, this further involved him as a co-analyst in systematically checking the data and interpretations.

Fifth, I translated my daily participant-observations and close conversations with the participants into a detailed written description of the research setting and the participants' lifeworld. Such "thick description" (Denzin, 1989) establishes credibility by providing verisimilitude for the readers to evaluate if the account is credible and applicable in other settings. Besides the earlier section that describes the research setting and participants, chapter 4 also provides a nuanced and rich description of the students' lifeworld, literacy practices, and funds of knowledge. Chapter 6 also takes a particular conversation and provides a rich amount of discursive details at a micro-genetic level. Thus, the detailed and elaborated writing in those chapters is also another way of establishing validity.

Sixth, I engaged in peer reviews during coursework and support groups by asking colleagues to review and check my developing interpretations along with the supporting evidence. In chapter 8, I also involved a colleague who was not involved in the research study to independently code 20% of the student essays in order to determine inter-rater reliability. Furthermore, I presented some of my findings and analyses at several peer-reviewed conferences and received valuable feedback and validation.

Lastly, according to Gee (2010), an important element of validity for discourse analysis is the attention to details in the linguistic (and I would add semiotic) structure. A discourse analysis is more valid if "the analyst is able to argue that the communicative functions being uncovered in the analysis are linked to grammatical devices" used by the "native speakers" in making specific meanings in their communities (Gee, 2010, pp.123-124). Throughout my analysis, especially in chapters 5 and 6, I used the rigorous discursive methods informed by SFL and social semiotics to examine the linguistic-semiotic details made by the participants in order to further warrant my claims.

Chapter 4

Connecting Youth Lifeworld:
Trajectories of Texts, Experiences, and Funds of Knowledge

This chapter provides an ethnographic description of the students' out-of-school texts and literacy practices in relation to the topics of mechanics and electricity. Because my research drew heavily on the students' choice texts, a requisite step was to understand the background that influenced the selection and interpretation of these texts. Through the analysis, I show that the students' choice texts were intimately connected to their out-of-school activities, experiences, and funds of knowledge. The purpose of this analysis is to account for how their attitudes toward science were embedded in their experiences in and social affiliations to certain communities. This account will aid a more complete understanding of their out-of-school texts and discourses before focusing on how they contrast with school physics discourse (in chapter 5), and subsequently how the various discourses were bridged through hybridizing understandings (in chapters 6 and 7).

Overview of Choice Texts

I begin by presenting the nature of the choice texts collected from all the students. I categorize these texts according to the various categories in media, source, and interest topics. Tables 3 to 5 show their distribution in each of the two cycles of mechanics and electricity.

Table 3. *Breakdown of Choice Texts by Media (N=33; 30)*

Media		Cycle 1	Cycle 2
Websites		14	19
Videos (include TV, YouTube)		17	4
Printed articles	Magazines	2	1
	Instructional manuals	0	5
	Company quotation	0	1

Table 4. *Breakdown of Choice Texts by Source (N=33; 30)*

Source		Cycle 1	Cycle 2
Profit-driven commercial	TV	8	2
	Website	1	4
	Print	2	7
Educational	School-based educators	6	0
	Non-school (e.g., museum, how-to sites)	2	6
	Students (for school assignments)	10	0
Interest groups		2	7
Personal sites		2	4

Table 5. *Breakdown of Choice Texts by Topic (N=33; 30)*

Topic		Cycle 1	Cycle 2
Sports		22	0
Automobile/ Transportation	Conventional gasoline vehicles	4	0
	Hybrid/electric vehicles	0	8
Consumer Technology		1	10
Alternative Energy Sources		0	6
Natural/man-made disaster		0	5
Music/Music appliances		2	0
Science Fiction (e.g., Lost, Matrix)		2	0
Space-travel		2	0
Human Body		0	1

In the first cycle on mechanics, sports was the major topic that majority of the students (67%) were interested in and recognized as having some connection with physics. Gender difference played a distinctive role in the type of sports selected. Texts about football, hockey, basketball, archery, bowling, BMX, golf, skateboarding, and skiing were all selected by male students while texts about soccer, cheerleading, colorguard, and running were chosen by female students. All the texts about football and hockey, five in total, came from a TV series called *Sport Science*, which was aired in Fox Sports Net from September 2007 to April 2008. The rest of the male-dominated sports texts were mostly websites found on the Internet from a range of sources including former coaches, sports enthusiasts, and museums. Among the female-dominated sports, a large majority of the texts were videos from YouTube and many were made by students all over the country for their school science projects.

After sports, the next major topic was automobile with four texts (12%) all chosen by male students. Three of these texts came from *MotorTrend*, *Top Gear*, and *Popular Science*, which these students subscribed to and read regularly. The remainder of the texts from the first cycle (21%), all from male students, dealt with a range of diverse topics such as music, science fiction, and space-travel.

In the second cycle on electricity, the topics were more evenly distributed with four distinct categories (see Table 5). The first category on consumer technology (33%) was about the operation of certain electrical devices. Five of these texts came from instructional manuals that accompanied the students' electronic gadgets, such as digital camera, PlayStation 3, and Nintendo DS. The other five texts were websites that explained how common devices work (e.g., battery, computer circuit board). The second category was on hybrid and electric vehicles (27%), which given the hype surrounding new models of hybrid and electric cars, generated a lot of interest among some students. Most of the students who brought texts on automobile in the first cycle continued to bring texts about cars, albeit with a different focus on battery-powered fuel rather than speed, acceleration, and horsepower. Apart from two female students, all the texts in these two categories – consumer technology and hybrid/electric vehicles – were selected by male students.

The third category was about alternative energy sources and technologies such as solar panels, wind turbines, and smart grids (20%). Two of these texts were created by companies selling solar panels, three by various interest groups such as *American Wind Energy Association* and *Endependence*, and one from *Popular Science* magazine about the dire energy situation in the U.S. This was the only category with a gender balance. The last category was about phenomena related to static electricity (17%); three of them were about lightning and two about explosions at a gas station caused by static charge. All the texts in the last category were selected by female students, and they came from a range of sources such as the TV program *Mythbuster*, various how-to websites, and an online version of *Wired* magazine. Lastly, there was one unique text from a female student, which was about the electrical function of the human body. This text was taken from *answersingenesis.org*, and was written from a creationist perspective.

Comparing across the two cycles, there were several notable changes in the choice of the texts in terms of media and sources. The most visible change was a sharp decrease in the number of videos and student-generated texts and a corresponding increase in the number of print materials and websites. Based on the interviews, these changes occurred because the students found it was more difficult to analyze videos or student-generated texts for the assignment, and thus adjusted their choices to suit academic expectations.

Understanding Youths' Uses of and Experiences with Texts

Throughout this chapter, I elaborate the students' text choices and show how they were related to their life trajectories of experiences and social affiliations. This will be followed by an analysis in chapter 5 on the discourse implicated in these texts, and subsequently how they mattered to the students' learning of school physics in chapters 6 and 7. This organization is deliberate as, before I focus on the content of specific texts, it is important to understand the larger picture of why and how the students' texts were read. Analytically, this is to prevent the discourse analysis in later chapters from being too "text-driven" by focusing solely on the students' texts and ignoring the larger picture of the readers' uses of and experiences with them. Overall, the goal of this chapter is to account for how students' views toward certain aspects of their life (including science) were embedded in their use of texts, experiences, and social affiliations to certain communities.

From a study on the literacy practices of youth in one urban community, Moje et al. (2008, p. 107) found that adolescents read and wrote outside school for a diverse variety of reasons, including "the maintenance of social networks, the development of subjective experiences and enactments of identity, and models for self-improvement and achievement of future goals." In this study, there was no exception in the literacy practices for the adolescents I observed. Thus, for these students, it is important to understand why they read certain texts related to mechanics and electricity, how they came about reading them, with whom they read these texts, how often, using what media and technology, what similar texts (or intertexts) they read and created other than the specific choice texts they brought, and lastly, what they experienced as they read their texts.

Literacy Practices as Dispersed Network of Intersecting Human Activities

In addressing these questions, a major theme that emerged from my analysis is the interconnectedness of their literacy practices with their lived experiences and participation in activities spread across time and events. This led to the main assertion in this chapter that literacy practices, or ways of using and engaging with texts, formed part of a dispersed network of human interactions connecting young people's lived experiences across a wide range of people, affiliations, material objects, localities, and temporalities. First, in a chain of activities across time and space, texts and youths' lived experiences formed a reciprocity where they co-existed and mutually constituted one another. On one hand, youths' experiences were enriched by their *traversals* across multiple texts. On the other hand, texts themselves were *textualizations* of their and many others' experiences as they moved in and out of intersecting network of activities. Second, the texts that youths read and the associated experiences were embedded within their social affiliations with family, peers, community, and popular media. These affiliations provided the social and cultural funds of knowledge that shaped the students' attitudes and dispositions toward their out-of-school interests and activities.

The following analysis will illustrate these two categories in my assertion: (a) text-experience reciprocity across network of interactions dispersed over space and time, and (b) their embeddedness within social affiliations. At the same time, the analysis also serves to further illustrate four major theoretical ideas that I use to construct my assertion in this chapter: traversal, textualization, circulation, and funds of knowledge (see literature review). To summarize, traversal focuses on the semiotic and phenomenological trajectory of an individual as he/she moves across texts, settings, and activities (Lemke, 2005). Textualization is the process whereby individuals, through their traversals, transform part of their experiences into texts through a symbolic system (Bloome & Egan-Robertson, 1993). Circulation is the physical movement of, and consequently interaction among, texts and individuals (or actors more generally; Latour, 2005) as they crisscross through networks of activities over space and time, or simply space-time (Leander & Lovvorn, 2006). And finally, funds of knowledge are cultural capitals that an individual appropriates from his or her social environments (Moll, et al., 1992), and as I show later, are categories accounted for by traversal, textualization, and circulation.

I begin by illustrating the first category (text-experience reciprocity) where I make a connection between the students' choice texts and their lifeworld experiences. Because of the diversity in the students' topics, this will be presented in two sub-categories: one focusing on sports, which was a major topic during the first cycle, and the other on general reading interests and habits. This will be followed by an illustration of the second category (embeddedness within social affiliations), where I show how the students' selection and usage of texts were connected to their funds of knowledge. Figure 6 presents a key linkage chart for my main assertion and categories.

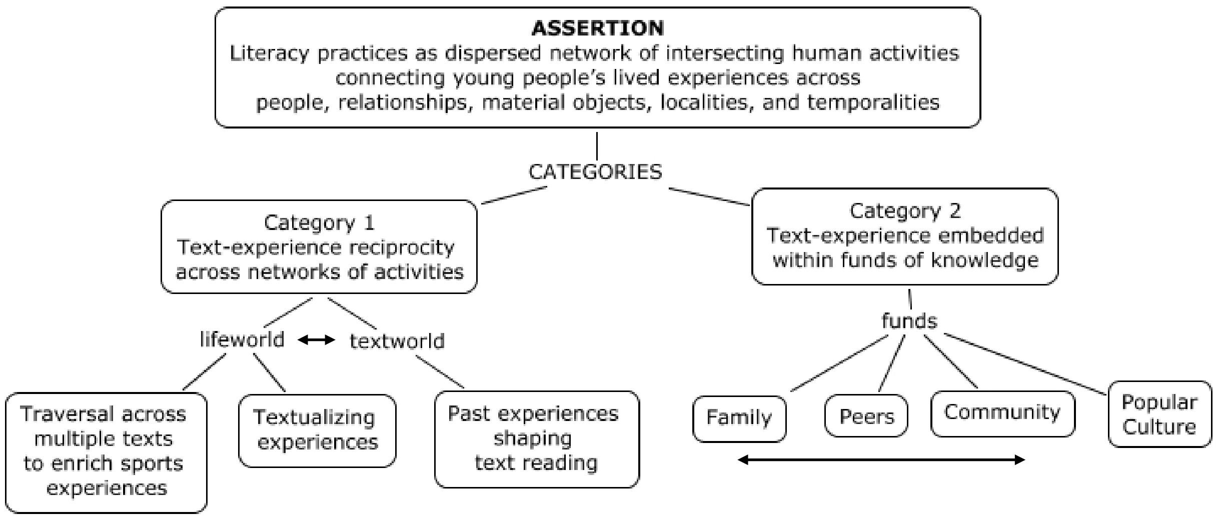


Figure 6. Key linkage chart.

Text-Experience Reciprocity across Network of Activities

For the first category, there was a tight linkage between the students' texts and their regular non-academic activities. This was most visible in the area of sports where the students attributed their passions for and active participation in their sports as the main reasons for selecting their choice texts. They often described their sports as their "life," that is, what they do, who they are, and who they want to be. This can be seen from their journals where they wrote about their selection rationale. Many of them (43%) justified their choices by the frequency and intensity of their sports activities; for example: "color guard is my life and I use this stuff 4 days a week" (Evelyn), "I shoot a basketball almost every single day of my life" (Mike), "I have soccer practice 6 days a week and most, if not all, of my time is invested in it" (Sabrina), and " I dedicate a lot of my life to [BMX] and I have been doing it for about 9-10 years" (Zac). Others (29%) wrote about how they saw themselves as integral members of their sports like, "I am an avid bowhunter" (Jason), "I'm a Sr. member of Victoria High Colorguard" (Lucy), and "As an adult I hope to have a career related to the sports industry" (Hermione). These examples are one of many evidence that the students' choice texts were purposefully selected to be representative of what they did outside the school curriculum.

Besides sports, the remainder of the choice texts was also closely related to the students' other regular activities such as reading magazines, watching documentaries, and surfing the Internet. These students related their interests to a wide range of topics as shown in Table 5. On the surface, the nature of these activities differed from those related to sports. In comparison, they can be described as more "text-centric" in that the activity involved focuses on the interaction with the text itself. For example, the activity of reading a car magazine involved a material and semiotic interaction with the text in question so much so that the immediate activity (e.g., reading) could not exist without the text. On the other hand, the activity of playing a sport like soccer, which was often seen as more "experiential" compared to reading, did not require as much interaction with the texts that the students would read about soccer (at least within a bounded timeframe of a soccer match or practice)[3].

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[3] To overcome this "experiential" versus "text-centric" dichotomy, a more sophisticated approach is to treat any kind of experiential activity as a text in its own right. For instance, when someone is playing soccer, her surroundings such as the positions of her teammates, rivals, goal poles, and the soccer ball can be read semiotically as a text, which she would need to derive its dynamic and situated meaning in order to navigate successful within this "text." A person driving a car also needs to read the different signs (e.g., street lamps and signs, position of other cars, indicators in the meters, sound of the engine) holistically as a text. However, as I recognize that this can be somewhat confusing in my terminology considering that I am using "text" more in the conventional sense of denoting printed articles, websites, or videos that students read and brought to the classroom, I shall refrain from the usage of this word and continue to refer events like playing sports or driving a car as experiential activities.

Because of these differences, I initially drew a distinction between the "experiential" activities in sports and the "text-centric" activities with media (e.g., reading, writing). For the sake of this discussion, I call this the lifeworld and textworld distinction. It could be said that lifeworld experience involved a personal involvement with some direct events, while reading a book, watching a show, or playing a video game were indirect "second-hand" experiences, so much so that any meaning and feeling derived from reading about an event was deemed not as rich as if one had experienced it "first-hand" in life. However, a deeper analysis revealed that this distinction became fuzzy as the timescale was expanded to incorporate other localities and temporalities beyond the immediate boundary of the activity in question (e.g., playing a sport or reading about that sport). On one hand, students who engaged in a certain sport did not just play or "experience" the sport, but at other times, they also consumed and produced texts that were associated with it for a variety of reasons. On the other hand, students who read about some topics did not choose to read and interpret the text in isolation from their lifeworld experiences. This mutual interconnectedness, which I call text-experience reciprocity, was observed in all the students that I interviewed.

I will elaborate this text-experience reciprocity by examining the sports played by the students and the accompanying texts they read. I start by foregrounding their lifeworld participation in their sports, and then tracing the written and oral texts (i.e., textworld) that supported their lifeworld activities in various ways. Although my data only allow me to frame the analysis in the domain of sports, it is likely that my claims can be generalized to other "hands-on" activities such as driving a car or installing/repairing an electronic device. Next, I reverse the direction by first considering the students' textworld of reading (for non-sports related topics), and then tracing their lifeworld experiences that shape their engagement with the texts they read. Considering these two aspects of the reciprocity both at once, what I aim to show is that texts and experiences depended on each other as they jointly regulated and co-constructed the students' ongoing activities, be it playing a sport or reading a book. Understanding this text-experience reciprocity is key to understanding the students' selection of and experiences with their choice texts.

Traversal across multiple texts to enrich sports experiences.

In six interviews with students who chose texts related to their sports, I started by asking grand tour questions (Spradley, 1979) to get them narrate their involvement in the respective sports. Every student talked about having to go for practices or training during weekdays (ranging from two to five times a week) and the occasional matches or competitions during the weekend. What was involved in these practice and training sessions were general physical exercises (e.g., running, gym workout) that cut across different sports as well as repeating routines that were specific to each sport; for example, pitching a baseball, dribbling a soccer ball, making a bull rush in American football, doing a jump in cheerleading, perfecting a toss synchronization in colorguard, or executing a manual in BMX. Although each routine was different for every sport, the reason for doing them was similar for every student, which was to improve their techniques and eventually become a better player in their sports.

Although practice and training sessions constituted a major part of the students' experiences in sports, they were not the only activities. Engagement with texts in various forms was also related to their sports activities. One major aspect was reading to know the techniques used by expert athletes and coaches to make oneself perform better. An exemplar came from Benjamin, who went online about once every week to look up information on baseball techniques in order to, in his own words, find out "what can make me better, and what I can do to change." Besides websites that he searched and chanced upon, one of the websites he visited regularly was *pitching.com*. This website, recommended by Benjamin's coach, was created by a former pitcher and coach, and had numerous articles and videos on improving pitchers' performance and safety records. When asked about what he read on these websites, Benjamin spoke about the "new things coming out like how you can throw the ball a little differently to get that extra movement. A little bit to help the edge." One specific example he gave was a certain technique used by pitchers to throw a curveball that minimizes injury to their elbows.

Such literacy practices complementing sports techniques and performances were also mirrored by other students. Zac read BMX articles from the website *espn.com* and magazine *BMX Today* once or twice in every few weeks. He talked about wanting to learn "the different techniques… that might teach [him] how to jump better, or do a manual[4] better." He also regularly watched videos on YouTube that showed regional and national BMX races so as to keep track of the "local pros to see what they do" and for himself "to get better."

Besides improving one's sports techniques, there were also wider purposes that motivated students to read about their sports. One purpose was for competitive athletes to keep themselves updated on the events in their sports, such as competition dates and

[4] A manual is a stunt used by bikers to lift the bicycle's front wheel and ride on the back wheel, and was the main topic discussed in Zac's choice text.

venues, results and rankings, and profiles of teams and players. Zac regularly visited the website of the National Bicycle League (*www.nbl.org*) not only to keep track of his points and national ranking, but also update himself with new information from the league. This was similarly reflected in Lucy, who as a colorguard, often visited the Winter Guard International website (*www.wgi.org*) to check her team's scores and results and browse through new pictures and videos of recent competitions. Furthermore, these students also updated themselves on national and international competitions and the performances of their favorite teams and players.

These examples illustrate that a sports player often traversed across multiple texts for purposes related to their lifeworlds in sports. These texts consisted of a mixture of regularly subscribed magazines, frequently visited websites, and randomly browsed and chanced upon sites. In this traversal, students selectively read portions of the texts and construed meaning in combination with their physical involvement and participation within their sports. Due to the regularity between their readings and sports practices or matches, there was an interspersed alternation between their textworlds and lifeworlds, such that what one read was influenced by his/her sports participation, and reciprocally, what one did was also informed by his/her readings. Thus, if the life trajectory of any student was analyzed, the traversal taking place would cross the boundaries between events spread over different times and locations (e.g., going for practices, reading for tips and techniques, participating in matches, talking about their experiences). As such, the meaning that a student made in any activity was not bounded to its local space-time context, but was always distributed across many activities spread over time and places.

The analogy of a traversal is useful here because it conveys the idea that when a student read any text, it was not simply about information gathering or sense-making from that single text alone. Rather, it involved a movement, semiotically and phenomenologically speaking, across multiple texts, media, sites, events, and activities, and across both text- and life-worlds. Thus far, I have only illustrated the traversal from text to experience and vice-versa of a single individual. In the next section, I show how within a dispersed network of intersecting activities, traversal is also useful in accounting for how experiences, through textualization, were made mobile and circulated and shared across many people in a community.

Textualizing experiences.

Within this traversal across texts and experiences, enriching one's techniques in sports was not confined to reading about it in textual and visual modes (i.e., websites, magazines, videos), but was also orchestrated using oral and gestural modes as the students talked about their experiences with their coaches and peers. This is where experiences were *textualized* into a publicly visible form rendered for communication and sense-making (Bloome & Egan-Robertson, 1993). As a result of their participation in competition or practice sessions, players and coaches often related their experiences using a language system, thus textualizing those experiences into a set of words, phrases, and gestural actions. Through repeated usage in a long network of activities over time and place, these words and actions eventually developed into some kind of adages, techniques, or strategies that athletes remembered and used to guide their actions in the field. This was seen from the way the students talked about their practice sessions. As an exemplar, consider Naomi's narration of her cheerleading practice:

> So there are two bases and then there is a flyer, which is the top, and then the back spot. And the back spot like holds the flyer's ankle all the time. And they help them like get up there and stuff. And so the bases, like the *biggest saying, they teach you is: "don't use your arms, you have to use your legs."* It's because you don't want to go like from here cos it's more. it's harder to push up from here, and it's easier to push up through your legs [Naomi demonstrated using her body]. So that's what they teach you, I guess. And they get mad at you if you. they like always like: "use your legs, don't use your arms" cos you're not supposed to like bend your arms. Cos you'll like collapse.

In Naomi's narration, the technique that base cheerleaders used to push their flyer up came about as a kind of "saying" (i.e., "don't use your arms, use your legs") that "*they* teach you." Though not explicitly stated, it could be inferred that "they" refer to the coach and senior cheerleaders, whom through their past experiences, knew it was important for the bases to use their legs instead of the arms. Textualization first occurred when these instructors translated their bodily experiences into a verbal saying, which then became an instructional phrase and strategy communicated to beginning cheerleaders. In the above excerpt, the communication of that textualized experience to Naomi was evident as she narrated part of the event using direct speech: "don't use your arms, use your legs", thereby "projecting" the source (Halliday & Matthiessen, 1999) of that experience to her instructors. Furthermore, as Naomi could remember and relate what was taught, this shows the textualized experience had become an effective guidance that mediated her and her teammates' cheerleading stunts.

Another example came from Lucy, although in her case, the role was reversed as Lucy was a senior member of the school colorguard team and she often coached junior members on the various tossing techniques used in colorguard performance. In the following excerpt, she related an incident where she taught someone based on her experience:

> Lucy: There's different weights at either ends of the pole. So it's heavier at the top and lighter at the bottom. And a lot of the time, I have to tell people to like, cos if you just try to make it flat and don't squeeze it, gravity will pull it down [Lucy gesturing with both hands]. *So I just have to tell a girl on the other day "you got to squeeze, don't let gravity control you"*
>
> Interviewer: How do you know this? Did you read from somewhere or is it through experience?
>
> Lucy: It's between what people told me and what I learn from doing it myself.

Similar to Naomi's textualization, the experience of handling an uneven weight distribution of a pole was textualized into a kind of saying ("you got to squeeze") and eventually became a verbal instruction of "squeezing" during the toss. This instruction was being passed from Lucy, a self-described veteran, to a girl (presumably a rookie) so as to help her improve her tossing technique. Lucy's reply to my follow-up question was illuminating as she recognized this embodied knowledge was gained "between what *people told me* [textualization] and what I learn from *doing it myself* [experience]." In other words, the squeezing technique came from a combination of some prior textualizations (from Lucy's seniors) and Lucy's own bodily experience. This shows the tight integration between textualizations and bodily experiences with phenomena so much so that they were almost inseparable as shown in Lucy's response to how she knew about the technique.

These examples illustrate two sequential mechanisms of textualization: compression and mobilization. First, textualization compressed one's past experiences spread across distant time and places into a specific text bounded within the present of a specific time and place. Next, once experiences were compressed and textualized into some material product (i.e., text), they were rendered mobile as they could be circulated through networks of people, texts, and activities. This mobility enabled someone's experiences to be transported from a bounded time and place where it was first textualized and distributed to future events for oneself and other people. Compression and mobilization were thus important mechanisms for the reciprocity of text-experience as they reinforced each other to connect students' traversals across events and time.

For verbal and gestural materials produced during an event (e.g., training session, conversation), the mobilization of experience was made possible by the circulation of people involved as they caught on to what was said during the textualizing event, and later moved to another place and reproduced them for another event. This was seen in the example where Naomi recalled the textualization made by her coach and senior cheerleaders about using the legs instead of the arms, and she subsequently reproduced them elsewhere, including the interview conversation. Furthermore, Lucy's examples also show how a chain of text-experience over time was formed when former experts passed their text-experience on to current veterans like Lucy, who then passed it on to junior members like Naomi, who would also eventually pass it on to future rookies. Thus, through the movement of people in and out of communities, this was how circulation could be extended beyond an individual's trajectory to a long and dispersed network involving other people. Such *circulation of text-experience* was how any community like a school team could maintain some continuity of its norms and practices over time through textualization and the circulation of its texts and members. As I further elaborate in a later section under community funds of knowledge, this was also how discourses were formed and maintained within and across communities.

Past experiences shaping text reading.

Just as texts complemented and enhanced students' lifeworld experiences, their past experiences with phenomena also influenced and shaped what and why they read certain texts. This was somewhat illustrated by earlier examples from sports where their experiences motivated what they chose to read, for example from *pitching.com* or *BMX Today*. However, in this section, I consider other topics that interested the youths other than sports, and also highlight a major difference between sports and the other topics in terms of their reading purposes. In sports, I have shown that much of their readings were tied to their social identifications with their school/community sports teams and their desire to become a better player or athlete. By contrast, for the topics I present later, the purpose was generally related to the sheer joy, excitement, and curiosity in reading certain things that interested them. During the interviews, students often related some prior personal events and encounters beyond the texts they were reading that sparked off their interests. In other words, these students chose to read and interpret their textworlds in connection to some related lifeworld experiences.

I show two examples to illustrate some of the experiences that shaped why several students read about other topics. In relation to electricity, one of the more popular media selected by the students came from the science entertainment TV program *Mythbuster*. Lucy's explanation on how she ended up watching *Mythbuster* on a regular basis was one of the most telling in terms of how past experiences shaped the kind of TV programs youths liked to watch:

> Interviewer: You mentioned in the forum that you like Mythbusters. Tell me more about it. Why did you like it?
>
> Lucy: I don't know, me and my dad watch it, so it's just like. We're not really analyzing anything, but *it's fun to watch, they blow stuff up* (laughter). It's kind of like when I was growing up in our neighborhood, you know in the books when you read like the neighborhoods who do the crazy little. they try to invent things inside that. That was the neighborhood that I grew up in. And I still live there, but we're not as tight anymore. But like we build a hovercraft, and we like had a giant fort, and we always building stuff and bottle rockets and stuff. So, I don't know*, it kind of make me think of that kind of stuff, so I like it*.

In the beginning of the interview, Lucy explained with a little sense of humor that *Mythbuster* was "fun to watch" because "they blow stuff up." While it is to be expected that most teenagers are excited about anything being blown up, Lucy provided a reason from her childhood that further illuminated why that was "fun to watch." From her recount, it was not just the explosion itself from *Mythbuster* that made it exciting, but rather the parallel "crazy little" stuff and inventions carried out in *Mythbuster* that reminded her of a memorable part of her childhood. Her later description of some of the "crazy stuff" they did in her neighborhood showed some of the similarities that made her draw the connection to *Mythbuster*: the handyman approach to construction, the many trials and errors, and the construction of ridiculous objects for fun and humor.

Furthermore, her frequent laughter suggests that the intensity of those memories and their meaningfulness to her. Thus, for Lucy, these memories served as a bridge between her lifeworld of growing up in a neighborhood that "invent things" and the textworld of *Mythbuster*.

The second example illustrates how a personal encounter with a dramatic natural phenomenon could also shape what students read. In the following excerpt, Sabrina gave a rather interesting rationale for choosing her text about lightning. She wrote in the forum:

> This topic I picked is personally ironic. I like learning about natural disasters and natural phenomenons [*sic*] such as lightning but *only on paper*. I have an irrational fear of storms haha. So when a storm comes I hate it but when I watch about them on tv or read about them I really enjoy it. It is a *love hate relationship*.

Sabrina was the most explicit in drawing a clear distinction between her lifeworld experience "when the storm comes" and her textworld which existed "only on paper" and "on TV." The lifeworld invoked personal distress and fear while the textworld brought a sense of enjoyment. Yet, these two aspects complemented each other because there was, as Sabrina expressed it, a "personally ironic love-hate relationship" between experiencing the phenomenon and reading about it. This example shows clearly the text-experience reciprocity, and it not only embodied the more positive feelings such as desire (for Hank) or nostalgia (for Lucy), but also fear, which was indirectly linked to a sense of wonder and amazement.

When I first interviewed Sabrina, it was difficult initially to understand her "love-hate relationship" for storms. However, several months later, as a series of severe thunderstorms and tornado warnings hit the region, I encountered firsthand the mixed feeling of trepidation and excitement of experiencing a Midwestern severe thunderstorm. Once, I even sought shelter in my basement because of concern over my family's safety, while at the same time, excitedly tracked the development of the tornado in my vicinity over the Internet. Having spent much of my life in a country free of natural disaster (for which I am thankful for), that personal experience helped me relate to Sabrina, who grew up in the Midwest since she was four years old. In other words, Sabrina was interested to read an article on lighting not just because of the written description and its many appealing photographs, but because she had linked the text to her past experience of witnessing a severe thunderstorm. Furthermore, my own traversal from a severe weather event to Sabrina's choice text provided the basis for me to understand and interpret her "love-hate relationship" for storms. This further supports the importance of text-experience reciprocity in our selective choices and appreciation of texts.

Thus far, I have explored the relationship between text and experience and illustrated the rich diversity of youths' lived experiences (e.g., practicing a sports technique, participating in competitions, driving a car, building stuff, going on fieldtrip, witnessing severe weather) that supported and enriched what they read from various sources and media. From their examples and the idea of a network, I argued that reading was not simply an interaction with texts alone, but always incorporated one's experiences in a mutually constitutive and reciprocal way. At the same time, when embodied experiences were translated into texts through textualization, text and experience form an inseparable entity (text-experience) as they reinforced each other in connecting individuals' traversals to a dispersed and intersecting network involving other people and their experiences. In the next section, I extend the analysis of this network to further include the social affiliations with their family, peers, community, and popular culture.

Text-Experience Embedded Within Social Affiliations

From earlier illustrations, it was apparent that many times the students did not engage in their out-of-school activities on their own, but were often accompanied by other youths and adults, and mediated by various media such as TV, magazines, and the Internet. This is the basis to examine these social affiliations in greater detail in this section. In particular, I illustrate the network of social affiliations according to four groupings of student funds of knowledge characterized by Moje et al. (2004): home, peers, community, and popular culture. Using the notion of an expanding circulation of text-experience in a network (from family to peers to communities), I show how these "funds" provided the social and cultural capital that shaped the students' attitudes and disposition (or habitus) toward their out-of-school interests and activities.

Family Funds.

Family funds was a major recurring theme that accompanied the students' traversal across texts and experiences relevant to science. In many of their descriptions, the students mentioned several activities involving their family members on a regular basis (e.g., playing sports, watching TV, fixing cars). One particular striking feature observed in these shared activities was that they began when the students were very young and the parents and/or siblings had been providing role models or encouragement for them to participate in those activities.

Sabrina provided an exemplar in which two of her favorite activities, playing soccer and watching “court drama” TV shows, started early within her family. Her interest in soccer began when she was four-years old while she watched her older brother play soccer. When I asked her why soccer was her favorite among all her sports, she replied:

> Probably because I just grown up with it the most. I started soccer first [among other sports that she played]. And my older brother did it, and my little brother does it, we're a whole soccer family, my parents do it, so. it's like in our blood.

Although by eight-years old, Sabrina had joined a community soccer club and played soccer six times a week with the club, her family was still very involved in her soccer life. For example, Sabrina’s father suggested posting a website to aid her college soccer recruitment process and helped to video-record her various soccer maneuvers for this website. Besides soccer, Sabrina also mentioned her passion for watching what she described as “court drama” shows such as *CSI* and *Law & Order*. She attributed this interest to her family’s “obsession” with these shows and how the whole family would frequently watch these shows together.

Another example where students’ preference for and habit of watching certain shows as part of a family funds of knowledge was seen in Lucy’s interest in *Mythbuster*. Earlier, it was shown that she watched *Mythbuster* not only because it reminded her of “growing up in a neighborhood that do crazy little things”, but also because she and her father watched it together. This illustrates that her affiliation with her father and their joint experiences (both the past of inventing stuff and the present of watching *Mythbuster* together) could not be separated from the intrinsic interest in the show. In a later conversation, she further elaborated that it was her father who first started watching *Mythbuster* and other science documentaries, and she caught onto it around the time she was in middle school.

From these examples, two emerging themes could be seen. First, their preferences and dispositions for some activities were first nurtured within the family when they were young and were maintained as they grew older. This gives a glimpse into the social conditioning of the habitus (Bourdieu, 1984) that was formed within the family and constituted an aspect of the students' identities as certain kind of people; for example, a soccer player for Sabrina and someone who liked watching stuff "being blown up" for Lucy. Besides nurturing and supporting the students' activities, the second theme was, for some activities, the intensity of participating with their families changed as the students grew older and got more involved in other activities outside the family. This observation has a direct relationship with the next sub-assertion that students built new networks of affiliations with their friends and community clubs as they grew older. This is where peers and community funds of knowledge become important.

Peer Funds.

Besides family network, peer funds was the next category that provided support and motivation for students' involvement in their out-of-school activities. This happened mainly because the students often joined their friends in taking part in a new activity and/or formed new friendships through their participation in those activities. Many of the students spoke about how they became involved in their sports because of their affiliation with the people involved. Lucy was perhaps the most expressive in this aspect:

Interviewer: What sparks your interest in colorguard?
Lucy: My friends did it. Like the season I started with my sophomore season, but it begins at the end of freshman, so a couple of my friends join at the end of eighth grade, and they just really like it.

Interviewer: What particular aspects do you like about it?
Lucy: It's something I never done before. I didn't know when I started but it kinda.. *they became my family*. Like they're a group of people around, and sadly, they're my only friends; we spent much time together.

When asked about how her involvement in colorguard started, Lucy immediately talked about her friends as the main source that prompted her to join the school team at the end of her freshman year. Furthermore, Lucy’s interest in colorguard was maintained by this group of friends, who through the time they spent together, had become like a “family” to her. Thus, these affiliations were strongly tied to Lucy’s involvement and experience with colorguard. Lucy’s description of her colorguard “family” was corroborated by my observation of her close interaction with two other colorguard members in the physics class (one of whom was Evelyn).

Lucy’s increasing involvement with her colorguard friends and her description of them as a “family” was particularly telling when I look back at her life trajectory growing up in a neighborhood that did “crazy stuff” and watching *Mythbuster* with her father since middle school. In both these events, I showed how she described a somewhat decreasing intensity in those affiliations. In the first event, while Lucy was describing her neighborhood of three families, she qualified that while she “still live there, [they’re] *not as tight anymore*.” Hence, as children grew up, they moved on to form new affiliations in new activities under different life circumstances. In the second event, as Lucy became more involved in colorguard with her friends in high school, she was not able to watch

TV with her father as often as she could. This was suggested from the following excerpt where Lucy talked about joining her father on an irregular basis after coming home late from colorguard practice:

> Interviewer: Do you watch other science documentaries like NOVA, universe, planet earth?
>
> Lucy: Not on a regular basis, but in my house, we have stuff like that all the time and I'll *get home from practice* and grab my dinner and sat on the crouch and my dad will be watching the show like that.

Thus, Lucy's habitus and funds of knowledge was not drawn from her family alone, but also from a wider network of friends who shaped her disposition toward colorguard and her frequent identification as a colorguard member. Furthermore, Lucy's affiliation with her friends seemed more important to her disposition than the physical colorguard practices she did regularly, thus suggesting one should not only look at the practices of a community, but also the social affiliations that sustained them. Furthermore, this example also presents a case where the habitus and funds of knowledge were expanding and changing because of the shifting intensity of one's time spent in different networks; for example, a shift from growing up in a neighborhood that became less tight, to watching a type of TV show with the family on an irregular basis, to the almost exclusive time spent with a group of close friends on a set of common interests. This trajectory pattern was not exclusive to Lucy, but was also observed in Naomi, Sabrina, Zac, and Benjamin.

This analysis illustrates that students formed new affiliations and changed existing ones as they frequently moved in and out of social networks; beginning from their families and expanding to peers and subsequently larger communities. Consequently, as they did so, they were forming a larger traversal across a wider network of texts, experiences, objects, and activities. Coupling this idea with the circulation of text-experience I talked about earlier in the last section, I will now show their increasing exposure and conditioning to different discourses through their participations in a community network.

Community Funds.

I use the term *community* in two senses of the word: one describing the *local* community that a student had direct and physical interactions with (e.g., neighborhood, school clubs, local church) and the other describing the *global* or *distant* community that a student was affiliated with through the sharing of some common practices, identities, and beliefs. A network trajectory perspective can be used to think about the connection between the local and global community as a matter of the length of a network, rather than some abstract notion where the global community "contains" or "contextualizes" the local community (Latour, 2005). For example, the colorguard team that Lucy spent much of her time with was a local community, whose members consisted of her peers, coaches, alumni, seniors, and juniors; all of whom had a direct relationship with Lucy and shaped in one way or another her dispositions for the practices of this community.

However, few communities ever operate in isolation where there is no movement of people, objects, and resources in and out of the community. Through the circulation of text-experience I explained earlier, any local community is never self-enclosed and self-defined, but is always simultaneously connected to other communities sharing a similar purpose and interest in another part of the world. Through such circulation, the notion of a *global* community of colorguards connected all over the country can be conceived, although the term *distant* community is more accurate. It is these connections that shape how people share certain common practices, and reflexively, how they see themselves and others within this distant community as fellow members. (The term *discourse* community is synonymous because as I will show later, members of this distant community also typically share a common discourse, and reciprocally, it is this common discourse that also ties the distant community together.)

Because of this connection between a local and distant community, the community funds of knowledge of a student gained by participating in a school team, club, or church was not confined to a local group. But through textualization and circulation, it was always extended to a wide and dispersed network of texts and people, and through this network, a common set of dispositions, beliefs, and ideologies. To illustrate this idea, I highlight one unique case involving Naomi's life trajectory in the church community. Although this example was atypical in terms of its chosen topic, it is a powerful illustration of the extended network of communities. At the same time, it is also an important case study that aids the understanding of how a certain disposition toward science was formed and maintained.

Naomi grew up in a Christian family, and together with her family, was an active member of a local community church comprising a few hundred believers. Like most churches, its activities included not only regular services on Sunday, but also a host of activities targeted at different groups within the church, such as bible study, Sunday school, and youth ministry. A few weeks before the start of the second cycle in the physics class, Naomi and her friend, Ashley, and both their mothers, enrolled for a six-week bible study class called Answers in Genesis. When it was time for the students to choose a text for the second cycle (on electricity), Naomi decided to search from a website called *answersingenesis.org* introduced to her during the bible study class. Because of Naomi's interest in Anatomy (she wanted to be a cardiothoracic surgeon), she chose a text explaining the electrical function of the human body (e.g., neural transmission, polarization of nerve membrane) from a creationist perspective. Through this text, Naomi and I, and sometimes with Brad, had many long conversations about science and religion.

I will elaborate in the next few chapters what was discussed in our conversations. For this chapter, my purpose is to show traces of the community funds that accounted for Naomi's knowledge and opinions, and through this, illustrate the extended network that stretched across a large distant community of Christian groups. Furthermore, I want to trace how a certain belief about evolution was shaped through her participation in this extended community network.

The class Answers in Genesis was designed and taught by a volunteer in Naomi's church called Lynn. According to Naomi, Lynn "went to different churches all of her life" before joining her church and "now she's trying to get the word out that the first couple chapters in Genesis are true, *and they are literal*." Lynn's creation class was modeled and titled after an organization called *Answers in Genesis* (AiG) founded by a well-known evangelist named Ken Ham. Tracing the history of AiG and Ham, one can find its roots from a local community church in Brisbane, Australia in the 1970s. Through 40 years of moving across and speaking at churches and organizations in various countries, partnering with numerous individuals, and distributing countless letters, emails, leaflets, magazines, and films, AiG has spawned into an international network with over 100 staffs and tens of thousands of subscribed members (see Ham, 2010). It has also produced several media (books, websites, DVDs), distributed monthly magazines and newsletters, launched a creation museum, hosted a regular radio program, and gave numerous talks around the world. Even from this summarized description, one can imagine the extended circulation of text-experiences across time and place that interconnect the knowledge and opinions of individuals who participate in this distant community.

For Naomi, her connection with the AiG network can be traced firstly to Lynn's movement to "different churches all her life" and her naming of the class as "Answers in Genesis." Furthermore, Lynn also introduced various texts from AiG which became the central teaching materials for the class. These texts and the way they were used were elaborated by Naomi's description of the class's literacy practices:

> Interviewer: How often do you read the book or this website?
> Naomi: I go to the class every Sunday for two hours. So that's weekly. And then we read stuff from the website [*answersingenesis.org*]. There's a zillion documents but we don't really look at them that often. We don't have time. But they're still there. We watch Answers In Genesis videos and we talk about it. We read the Bible. Then at home, I read Answers In Genesis book a little bit. I'm on chapter 8 or something, so I'm working on it, it's going to get there someday. I started just a couple of weeks ago.

The text that was most central to Naomi's class, other than the Bible, was a book compilation titled *The New Answers Book* edited by Ham (2007b). According to the class's syllabus, each participant was expected to read two or three assigned chapters from this book every week prior to the class in order to prepare for the discussion. Other important texts included the videos made by AiG, which generally feature interviews with creationists and scientists. According to Naomi, there was a mix of Christians and non-believers in the interviews: "some just give you information, but the others connect the Christian and the science together." Naomi found these videos very helpful because for her, "they are professionals who study on this and they are really smart scientists." Thus, through the traversal of these multiple texts, and the people who used them (e.g., Lynn), authored/edited them (e.g., Ham), and were featured in them (e.g., interviewees), Naomi's community funds of knowledge was stretched across a large distant community of creationists, and to their experiences and networks.

From her participation within this distant community, Naomi formed a certain view of evolution that changed her disposition toward what she was taught in Biology one year ago.

In brief, Naomi's current view of evolution was that "it doesn't make sense at all"; that "there was a bang" and somehow the world was perfectly created through the Big Bang and evolution. She felt that "it's really far-stretched for something to happen like that." Naomi also did not believe in evolution as it contradicted the *literal* interpretation of the Book of Genesis. This was extremely important to her because as she said, "if Genesis is the foundation of the Bible, and if you don't believe what Genesis says, then you don't really, and you shouldn't believe what the rest of the Bible says." As a result of her participation in the creation class, Naomi's views of evolution had changed, as she reflected in the following:

> Interviewer: When did you first start learning about evolution?
> Naomi: I learned evolution I think in fourth or fifth grade. And then in Biology last year.
>
> Interviewer: When you learned it last year, did you have a different view of evolution?
> Naomi: I think that before my [creation] class, I thought that evolution could have been possible, like Jesus could have will evolution to

> happen or whatever. But like through this [creation] class, I realize that, they don't even have like where are the bones, where are the fossils of one animal changing into another. They don't have any.

According to Naomi's self-perception, her view of evolution had changed significantly after the creation class. Drawing from Bakhtin (see literature review), Naomi had appropriated the voices from her community network and subsequently spoke from a particular discursive viewpoint. During our conversations, the multiple voices uttered through Naomi could be intertextually traced as I analyzed the various chapters from *The New Answers Book* (Ham, 2007b). One instance was the appropriation of the phrase "six literal days" that was made twice by Naomi. The word "literal" is a highly contentious issue that distinguishes different Biblical interpretations and is frequently discussed in many chapters of *The New Answers Book*. In those chapters, phrases like "literal days", "ordinary-length days", and "earth-rotating days" appear repeatedly. For example, in chapter eight (which Naomi had reported reading in an earlier excerpt), a particular passage reveals how Ham distinguishes his readers from other "mainstream" majority Christians based solely on the meaning of the word "days":

> The majority of Christians (including many Christian leaders) in the Western world, however, do not insist that these *days* of creation were *ordinary-length days*, and many of them accept and teach, based on outside influences, that they must have been long periods of time – even millions or billions of years (Ham, 2007a, p. 89).

This literal interpretation of Genesis is the most telling in differentiating the young-earth creationism, which Ham is speaking of, from other theories such as gap theory, day-age view, and theistic evolution. This distinction was alluded to by Naomi when she commented that a lot of people, "even if they go to church," do not go against evolution. Other instances that suggest Naomi's voice appropriation were the apologetic arguments used by Naomi to defend her beliefs. These arguments could similarly be traced to several passages in *The New Answers Book*, for example one of the chapters used the same arguments to question the nonexistence of fossil records of animals in the midst of evolving (see earlier excerpt from Naomi).

Therefore, through text-experience circulation and voice appropriation, it was not only Naomi who was speaking during the interview, but rather the many voices from the discourse of creationism speaking through her. This was an important process for the formation of her habitus and identity, and reciprocally, the continual maintenance of a young-earth creationist discourse. Likewise for myself, as I interacted with her, I did not present a unitary voice isolated from my own communities and networks, but also a mixture of discourses arising from my various involvement as a physics graduate, a science educator, a researcher, and a moderate evangelical Christian (see background of researcher; chapter 3). This heteorglossic nature of our conversation where the multiple discourses converged will be further discussed in Chapter 6.

Popular Culture Funds.

Thus far, I have discussed the social affiliations students have with the people involved in their life: family, peers, and community members. But as Latour (2005) would argue, their affiliations with non-human actors (i.e., material artifacts) were as important in sustaining their interests and activities, and thus constituted a major source of their funds of knowledge. From a network perspective, these material artifacts mediated the students' interactions with people, texts, and experiences across time and events. These interactions will be further discussed here.

The fact that students in the class were able to select their choice texts based on their interests was testimony to two aspects of their popular culture funds. One was the extensive media consumption of their life trajectory, which facilitated their encounters with numerous texts with potential connection to physics. The second aspect was their technological familiarity, or the know-how, in their media usage that made it possible for them to find, locate, extract, and deliver their choice texts for this project. These two aspects not only pointed to the students' rich cultural funds, but were also the basis for the possibility and success of Text-Synergy.

Although adolescents' consumption of digital media has often been criticized for their non-intellectual nature and irrelevance to school work, I found numerous examples where their media consumption could be channeled for school learning. I will show one example to illustrate how a personal use of the Internet became a useful resource that helped Sabrina's search for her choice text. Sabrina's text on the topic of lightning (see earlier section for why she chose this topic) was taken from *howstuffworks.com*, which is one of the most popular how-to websites. A how-to website is one that provides general information on a wide range of topics, including how specific natural and man-made things work and how to accomplish certain practically-oriented tasks. During the second cycle, six students including Sabrina brought their texts from various how-to websites. What was most interesting was the way Sabrina used *Howstuffworks* to locate her text. She came across *Howstuffworks* some years ago through her Internet usage, and had been using it since. She wrote in the forum:

> When I am bored I enjoy looking up random things on "how to" types of websites. You can learn a lot of cool things from them and this website I've been to before. So I went to the website because I thought it would be a good source and searched something related to electricity that went along with my interest.

During the interview, she elaborated that these “random things” were all personal stuff she enjoyed, such as how to make peanut butter and jerry sandwich and how to braid one’s hair. She disclosed she “don't do how-to for science stuff”, but after receiving the assignment, she figured she could “try it.” This shows that even though personal stuff and physics are topically disparate, Sabrina recognized the same website could provide a “good source” for “science stuff.” Moreover, Sabrina’s familiarity with and preference for *Howstuffworks* provided an important incentive for her to explore the science stuff. First, she would expect the science articles, though varied in content, would be written in a similar easy-to-understand manner, which was what had drawn her to *Howstuffworks* in the first place. Second, her familiarity with the website’s format and layout also provided further incentive for her to look at it. This example illustrates how how-to websites, which are popular and frequently used by adolescents, can be tapped for academic learning.

In addition, adolescents’ interactions with texts were also mediated by the symbolic association with pop icons. Many of the students’ texts focused heavily on celebrities and cultural objects that were greatly admired and desired. This was best seen in the very popular videos from *Fox Sport Science*, which featured one star player performing a physically challenging task in every episode. Examples include getting football quarterback Drew Bees to hit a 20 yards target with his throw and linebacker Ray Lewis to ram open a locked door with his bull rush. Besides featuring these athletes, the videos were also shot and edited to portray them as larger than life. These features, which were purposefully designed by the media producers to increase the shows' rating, evidently had a strong lure for the adolescent audience. Other celebrities similarly featured included Usain Bolt, David Beckham, Roberto Carlos, and Ben Roethlisberger. Automobile text was also another good example where the brand and model of a car (e.g., Ferrari) could invoke one's attention and willingness to read about it, as was the case for Hank. Overall, these pop cultural icons and the way they were presented through semiotic devices constituted a major component of adolescents' popular cultural funds of knowledge, and their impact will be further examined in the next chapter.

Summary: From Text to Network to Discourse

In sum, youths' out-of-school literacy practices, or ways of interacting with texts, were part of a dispersed network that connected their lived experiences across time, events, and people. This network included one's traversal from text to experience and vice-versa, and the circulation of shared textualized experiences within family, peers, and local communities. The network was also sustained and supported by the social affiliations with people and mediated by the use of media and cultural artifacts. Due to the interconnectedness of local communities, an individual's network could extend to a wide distant community that shared similar purposes and interests. As such, the students' funds of knowledge were not confined to a local group or area, but were distributed across a wide range of people and places. By participating actively in this extended network, students appropriated voices and developed certain attitudes toward some issues or situations pertaining to the community. This chapter thus supported the case I made at the beginning of this dissertation: it is not sufficient to simply investigate students' attitudes toward science without examining further how those attitudes were embedded in their experiences in and social affiliations with certain communities.

In the overall goal of recruiting and connecting to youths' literacy practices, this chapter highlights several positive as well as cautionary points. On a positive note, as youths' funds of knowledge were spread across a dispersed range of people and places, there was a rich diversity of topics, experiences, and media that could be tapped as resources for learning mechanics and electricity. More importantly, the students themselves were able to recognize these funds and bring texts that were thematically similar to the curricular content. Through the incorporation of these personal texts in Text-Synergy, most students felt it made classroom learning more meaningful and interesting. However, as youths participated in their out-of-school networks, they did not just gain knowledge from the participation, but also the encompassing discourses that shaped their attitudes toward those knowledge, which in turn shaped their positive or negative attitudes toward the academic knowledge from school discourses. Therefore, it is equally important to examine the underlying discourses constituted by different networks, and understand how their differences posed challenges for students learning school physics, both in terms of knowledge construction and attitudinal disposition toward that knowledge. This will be the focus of the next chapter.

Analytically, network and discourse are different ways of looking at the same phenomenon. A network view is analogous to a "street-level" view where the analyst looks at the paths (trajectories) individuals made in a labyrinth of streets and the interactions they made with other individuals as they crisscrossed one another's path. A discourse, on the other hand, is like a “city-level” view where the analyst looks at the patterns constituted by the streets and trajectories of collective individuals. While the network perspective helps the analyst trace the communities that provided the source for the students’ knowledge and dispositions, the discourse perspective examines the nature of those collective knowledge and dispositions, and how they contrast with one another. In particular, I will examine how the knowledge and dispositions from the out-of-school discourses contrast with the discourse of school physics.

Chapter 5

Contrasting Discourses in Intersection: Diverging Phenomena of Natural Events

In chapter 4, I showed how the students' choice texts were embedded in an extended network connected to their out-of-school activities, lifeworld experiences, and affiliations with families, peers, communities, and popular culture. Through such a network, texts and ideas circulated across and within certain groups of people, shaping them to share characteristic discourses and reciprocally maintaining and shaping the network that connected these people in the first place. In this chapter, I analyze the nature of these discourses and examine how they contrast with the discourse of school physics.

The contrast between scientific discourse and those that children and adolescents are familiar with have been well documented by many studies (e.g., Halliday & Martin, 1993; Lemke, 1990; Mortimer & Scott, 2003; Wells, 1999). However, these studies tended to cast the contrast between scientific discourse or language on the one hand, and ubiquitous terms like "everyday discourse" or "vernacular language" on the other. Although such a binary is useful in drawing out the peculiar features of science discourse, it masks the fact that "everyday" discourse is itself composed of multiple languages arising from a variety of activities in which today's youths participate.

Based on the diversity of the students' activities shown in chapter 4, this chapter illustrates nuances in the contrast between school physics discourse and multiple out-of-school discourses. In particular, five major discourses – sports, automobile, popular science, environment, and creationism were observed as Text-Synergy was enacted. The focus of this chapter is to show and explain how these various discourses frame diverging interpretations of the natural world according to their own semiotic and technological systems, and consequently how conceptual and affective conflicts arose as students related their out-of-school texts and experiences with the learning of school physics.

Overview of Discourses

Some Preliminary Words

I begin by addressing why these five discourses (sports, automobile, popular science, environment, creationism) are presented. As I have mentioned in chapter 4, a discourse is not an independent entity separated from the concrete trajectories of texts and people circulating in some networks. Rather, it is an abstraction of certain patterns that emerges and evolves from the networks over a long timescale. Such patterns involve some kind of recognition that people consciously or unconsciously make in every interaction. Because discourses are abstractions derived from interactions, they do not have distinct boundaries that can easily be pinpointed at any moment. First, discourses are always dynamically shifting and hybridizing according to the transient nature of how networks are assembled and dissembled. Second, how a discourse is discerned and labeled is always in relation to one's own discourses and positions in different networks. As such, I do not make ontological claims that these five discourses are universal and definitive categories that are always present in any physics classroom. Instead, they are patterns observed from a combination of many situated factors, including (a) the particular students' lifeworld and their contingent choices of text, (b) the type and extent of data collected, and (c) the researcher's sampling decisions, interest, and purpose.

Ultimately, the decision to group these five discourses rests on their usefulness for understanding the complex interaction of multiple discourses operating in a typical physics classroom. This has many advantages over the binary distinction between science discourse and the all-encompassing "everyday discourse". On the other extreme, I also avoid having too many specific sub-discourses ranging from every single sport, automobile aspect, environmental issue, and variant of creationism, as this distracts the overall focus of the analysis. For this reason, it is not so important to count the exact number of discourses or draw their precise boundaries, so long as the discourses that are analyzed (in a reasonable number) can inform how the students connected their diverse out-of-school experiences to the learning of school physics.

Although a discourse is a patterned abstraction and one can always organize them differently, this does not imply that these five discourses do not have a material reality and are "subjective" based on my own invention. On the contrary, these discourses (in whatever names and categories I formulate) had a real impact on the students' life in terms of shaping their sense-making, values, dispositions, actions, and decisions. While these students might not use the term "discourse" in their language, it was evident they could recognize the different patterns of coordination among words, actions, norms, and conventions from different sources. This recognition thus allowed them to know what was going on, and consequently, choose to act accordingly as such. At times, the different patterns between their lifeworld and school physics were quite incommensurable such that conflicts arose. I will show examples of such instances shortly.

Summary of Each Discourse

In this section, I provide a brief summary for each discourse as a context for understanding my main assertion. My purpose is not to comprehensively describe every aspect of a discourse, for such an account is beyond the scope of this chapter. Instead, I will only highlight features salient to the purpose of comparing out-of-school discourses with school physics discourse. For a more comprehensive account, one can refer to other sources (e.g., Coakley, 1990; Dryzek, 1997; Mellor, 2003; Parkinson & Adendorff, 2004; Piller, 1999; Roth, 1997; Sage, 1998).

Sports. The discourse of sports consists of the texts and textualizations in relation to the various sports that the students were involved in. Although each sport is uniquely different, there are common genres across every sport such as procedural technique, journalistic review, and sports science. Procedural technique texts are typically written by experts, coaches, and athletes on how to perform or improve certain routines specific to a sport. These are textualizations of the authors' sports experiences translated into words, and their dominant communicative function is instructive. For my analysis, I focus mainly on this genre because the students were most concerned with improving their practice routines through the reading of these texts (see chapter 4). Samples of these "how-to" texts include how to do a rifle toss, how to improve pitch velocity, how to perfect a basketball throw, and how to do a BMX manual. These texts are commonly found in sports magazines and websites. There are also numerous videos made by adolescents on YouTube that narrate and demonstrate visual-gesturally how to execute these routines.

Automobile. The discourse of automobile also encompasses a mixture of genres such as car reviews, reports of races or celebrities, repair and maintenance instructions, and advertisements. Most of the students' choice texts fall under the genre of car reviews due to the dominant feature of technical information about a car and its performances, such as top speed, acceleration, engine, fuel efficiency, comfort, and handling. Because some of these vocabularies overlap with physics, the car enthusiasts in the class were quick to recognize the suitability of these texts. Although the main communication function in typical car reviews is informational, they can also be evaluative and persuasive as the authors inject their personal opinions into the review. Furthermore, while automobile texts can be produced in all kinds of media, I focus only on print magazines and websites as these were the media selected by the students.

Popular Science. This discourse is the broadest and has the most diffused boundary among the five discourses. Popular science is loosely defined as the interpretation of science and technology by (or in consultation with) scientists/engineers intended for a general audience. The nature of popular science varies depending on their purposes and background of the audience. Because of my target group, I only focus on popular science texts that are widely accessible to children and adolescents through the mass media instead of scientific journalism geared toward professional adults such as the *New Scientist* and *Scientific American*. Common examples from the students include science documentaries like *Mythbuster*, *Sport Science* (overlapping with sports discourse), *Modern Marvel*, *The Universe*; magazines like *Popular Science* and *Popular Mechanic*; and books such as *Physics of Superheroes*. These texts are intended for commercial entertainment (with ratings and profit margins) as much as education for the general public.

Environment. Like popular science, environment discourse is also a broad category that encompasses texts with overt themes like alternative energy sources, climate change, global warming, and pollution. It also consists of a multitude of perspectives (see Dryzek, 1997). This particular category of discourse should not be confused with the discourse of *environmental science*, although the two are of course intimately related. Environment discourse is much more politically-driven compared to environmental science, which has a more academic and disciplinary character. As far as the students' networks are concerned, environmental texts tend to be scattered across their text-experience trajectories. For example, unlike the other discourses, there are few magazines or documentary series exclusively about the environment. I have also not found one student who actively and regularly read environmental texts from a regular source. Instead, the students' engagement with environmental texts occurred on a more sporadic basis. Nevertheless, students who brought environmental texts were quite informed of the debates and arguments from different sides of the conversation, thus suggesting they had come across specific environmental texts from time to time. Although environmental texts vary widely according to the issues at stake and the author's position, its communicative function tends to be persuasive and argumentative.

Creationism. This last category can be considered a special case built on the texts from one student – Naomi (see chapter 4). However, this does not imply that the discourse of creationism is not important for science learning. According to the first survey, 52% of the class attended a religious institution at least once a week (most likely

Christian or Jewish judging by the social statistics of the region). For these students, creationism could be a major concern as they reconciled what they learned in science with their faiths. Because creationism has a long history of conflict with science, it is crucial to examine its contrasting discourse in relation to school science discourse. Despite the fact there was only one student, the large corpus of texts that I collected from Naomi and my extended interviews with her were sufficient for an in-depth analysis of its discourse, which I will present in the later part of this chapter.

Diverging Phenomena from Multiple Discourses

In the above description of the five discourses, although it is apparent that each of these discourses deals with a different content, topic, or subject-matter, what I aim to show is that discourses are more than just contents; they are also characteristic ways of constructing content through language and technology. As Fairclough (1992, p. 128) argues, the use of the term *discourse* emphasizes that "areas of knowledge only enter texts in the mediated form of particular constructions of them." Whenever we are discussing a certain topic or making sense of some content, we always look at them from a certain frame set up by a specific discourse. In this sense, physics is not just an unbiased content or body of knowledge about some natural events, it is also a specific and specialized way of interpreting these events.

In the following analysis, I proceed to show how a common set of natural events can be framed and interpreted differently from multiple discourses. Because the students' purposefully selected their choice texts based on the perceived content similarity with school physics, this presented an opportunity for me to investigate how the students' out-of-school discourses intersect with school physics discourse when the discourses are dealing with common natural events. My key assertion is that each discourse frames a different phenomenon (or the interpretation of a natural event) according to its own semiotic-technological systems of semantic, visual, spatial-temporal, and intertextuality. When the students learned mechanics and electricity, the five discourses of sports, automobile, popular science, environment, and creationism became relevant in influencing some students to view certain natural events differently compared to school physics discourse. In other words, although these natural events created a common ground for the various discourses to come into conversation, there were also contrasting semiotic-technological framing that gave rise to conflicting viewpoints.

Let me first explain how I use and differentiate between the word “event” and “phenomenon.” I define events as the here and now of material things (including our human bodies) interacting and existing in the world. My ontological position is that events, in so far as they consist of physical matter, are real and material. A phenomenon on the other hand, from the epistemological view of phenomenology, refers to *perceived* events that we derive from our involvement in and experiences of the world (Schutz, 1962) as well as our use of technology (Latour, 1996). Although phenomenology often emphasizes the subjective experiences of individuals, I hesitate to add the word “subjective” to my definition as it suggests every individual can freely construct his or her own phenomenon based on their unique experiences. But as I have shown in chapter 4, our experiences are never individually-bounded in a fixed time and space, but are always distributed across circulating networks of texts, people, activities, and media. In this way, phenomena are often shared and socially constructed by groups of people according to certain configurations of a network (i.e., discourse).

This distinction between event and phenomenon is important in accounting for how two different groups of people can look at or talk about the same event, and be constructing essentially different phenomena and not really talking about the same thing. In other words, what is a phenomenon for some occurring events is not fixed and universal. Instead, it depends on the semiotic-technological systems available in a discourse that allow people to interpret the said event and construct a certain corresponding phenomenon.

I will illustrate the assertion that phenomena are framed by discourses by examining two separate sets of phenomena. The first set of phenomena, which occupied significant classroom time and presented challenges for many students, deals with the events of objects moving (e.g., traversing, falling, rising, and rotating). The narration of these events are fundamental to the discourse of sports, automobile, and classical physics. Based on the consideration of these events, I will elaborate four systems of semantic, spatial-temporal, visual, and intertextuality from each discourse, and how each is responsible for framing contrasting phenomena. The second set of phenomena deals with the electrical mechanism of the human nervous system, and illustrates the tension between the discourses of creationism and science. For this second set of phenomena, I will not elaborate the semiotic-technological systems as much, but will simply highlight the differences in the phenomena that are framed.

Phenomena of Movement

The various *events* that shape the phenomena of movement considered in this section include the following (the grouping according to these five bullets will be explained shortly):

(a) a baseball thrown horizontally, a racing car on a straight road, a runner on a 100 m track
(b) a colorguard tossing a rifle, a cheerleader jumping vertically into the air
(c) a basketball shot toward the basket, a football thrown or kicked forward into the air
(d) a skier or bicycle moving down a slope
(e) a spinning soccer ball, a cheerleader doing a somersault

From a sports or automobile perspective, every event listed above is arguably interpreted as a distinctive phenomenon. As later examples show, not many students could see or agree that these various phenomena can be considered collectively as one overarching phenomenon. However, that was what they were taught to see in the study of physics. First, all the above events (and many others) are typically organized according to the categories bulleted earlier. These categories are the phenomena of school physics objectified to be seen as five different *types of motion*, namely: (a) horizontal motion (uniform or accelerated), (b) vertical motion, (c) projectile motion, (d) inclined plane motion, and (e) circular motion. Each type of motion occupies one chapter or section of a chapter in the students' textbook, and for that matter, any typical physics textbook. Within each type, it does not matter which body is moving; what is relevant is the *motion* itself, where motion is an objectification of the process of moving bodies. Furthermore, these five types of motion can be further characterized as a single overarching phenomenon governed by a set of universal laws and mathematical equations.

As the unique semiotic features of science (e.g., nominalization, objectification, abstraction) have been extensively documented (e.g., Halliday & Martin, 1993; Kress, et al., 2001; Kuipers & Viechnicki, 2008; Lemke, 1990, 1998b; Martin & Veel, 1998), including my own previous work (e.g., Tang & Moje, 2010; Tang, Tan, Yeo, 2011), I will not say much in this area. Instead, I move on to examine the semantic, spatial-temporal, visual, and intertextual systems of the out-of-school discourses, and show how different phenomena are set up by these systems in contrast to the objectified phenomenon of motion in school physics discourse.

Semantic System.

I begin by analyzing the semantic patterns of several texts from colorguard, baseball, basketball, and car magazines. In particular, consider the following exemplar written by a former colorguard coach (Simmons 2010). I found this text by following a link from the Winter Guard International website, a site frequently visited by Lucy. This text presents an instruction on how to carry out a certain technique for basic rifle tosses. For brevity's sake, I am only showing portions of the instruction (see Appendix E for full text). In the excerpt below, the bulleted numbering and capitalized words were made by the author for organizational and emphasis purposes respectively, while those bolded were mine to highlight what I consider specialized lexical words of colorguard discourse. Within each bulleted numbering, I break up the paragraph into consecutive clauses/sentences so as to label them for analytical references. I also truncate parts of the instruction (shown by ...) in order to keep this excerpt short.

Excerpt 1: Colorguard Rifle Tosses (Simmons, 2010)

There are four parts to a **toss**: **push**, **lift**, **release**, **catch**. [1]

1. The **push** controls the rotations. [2]
   I like to use the tips of my fingers to drag down the butt of the rifle [3]
   like I'm slamming a door, but straight down, [4]
   lined up with my elbow… [5]
   Don't **push** the butt forward here or your **toss** won't be flat to the front (a.k.a. bad "**pitch**"). [6]
   The **push** happens half a count before the **release**. e.g., "five six seven eight AND one", [7]
   where you let go on one at the **release point**. [8]
   You can subdivide this (as in the exercises to the right) using the word "re-LEASE", with the emphasis on LEASE because that's when the hand opens. [9]

2. The **lift** raises the gun to the level [10]
   where you're going to let go of it. [11]
   Squeeze the left hand [12]
   as the rifle is pushed down [13]
   and transfer the energy from the swinging of the butt to the barrel. [14]
   As you **lift** straight up, [15]
   turn the left wrist like you are twisting a doorknob [16]
   and **lift** straight up in line with your shoulder… [17]

3. **Release** at shoulder for **single**, at chin for **double**, eyeball for **triple**, and barely overhead for **quad**… [18]
   Release straight up from your shoulder/elbow line - don't "**rainbow over**"… [19]

4. The **catch** for a basic toss is at **right flat**, hands at the grip and tip, wrists below elbows. [20]
   Wait at your **free hand** position until the very last moment to catch the rifle… [21]
   Releasing on *and one*, I catch a **single** on *two*, a **double** on *two and*, a **triple** on *three*, and a **quad** on *three and* [22]

A noticeable feature in this text is the use of specialized words or lexicon to describe the elaborated steps in making a rifle toss, as well as numerous taxonomic, spatial, and temporal relationships these words form with one another. These words and relationships are not only instantiated in this particular text, but are also frequently heard in Lucy's and Evelyn's talk about colorguard. For example, in chapter 4, there was an excerpt that showed how Lucy talked about instructing her junior to "squeeze" the rifle in order to go against gravity. This corresponds to line 12 in the text. The word *squeeze* is thus a common colorguard lexical word used at particular junctures corresponding to certain gestural actions when the "lift" is being performed [line 10]. During the interview, Lucy also mentioned "rainbow" [line 19] as another specialized word used in colorguard, and that its meaning was close to *parabola* as used in physics and mathematics.

Whenever people encounter specialized lexical words in a foreign discourse and want to connect them to their own discourses, the natural tendency is to translate or replace them with familiar words (e.g., from *rainbow* to *parabola*). This was precisely what the students and I tried to do during many of our exchanges (see next chapter for examples). However, such direct translation is never that simple due to the complex web of semantic relationships that lexical words in a discourse form with one another. Because the meaning of each word is contextually dependent on its relationships with other words within a discourse, that is, they form a "word concept" or "thematic pattern" (Lemke, 1990), one cannot easily replace a word from one discourse with a related word from another discourse without losing its specific meaning. To examine this further, consider the thematic pattern for the concept of a colorguard *toss*, as shown in Figure 7.

These four lexical words are then used to form certain spatial-gestural relationships so as to add meaning to the lexical concept of *release* [18]. This is then further condensed when *release* itself forms yet another relationship (a temporal one) with *push*, *lift*, and *catch* for the superordinate lexical concept of *toss* [1]. These nominalization and condensation features are similarly observed in other sports where common words like *pitch*, *jump*, and *shoot/shot* are condensed with elaborated meanings (always involving a sequence of bodily and gestural movement) in the sports of baseball, cheerleading, and basketball respectively. Arguably, these features play an important role in facilitating sports communication and instruction. This usage is also not very different from that of physics discourse where common verbs like “force” and “accelerate” are nominalized and condensed to become the central concepts in mechanics.

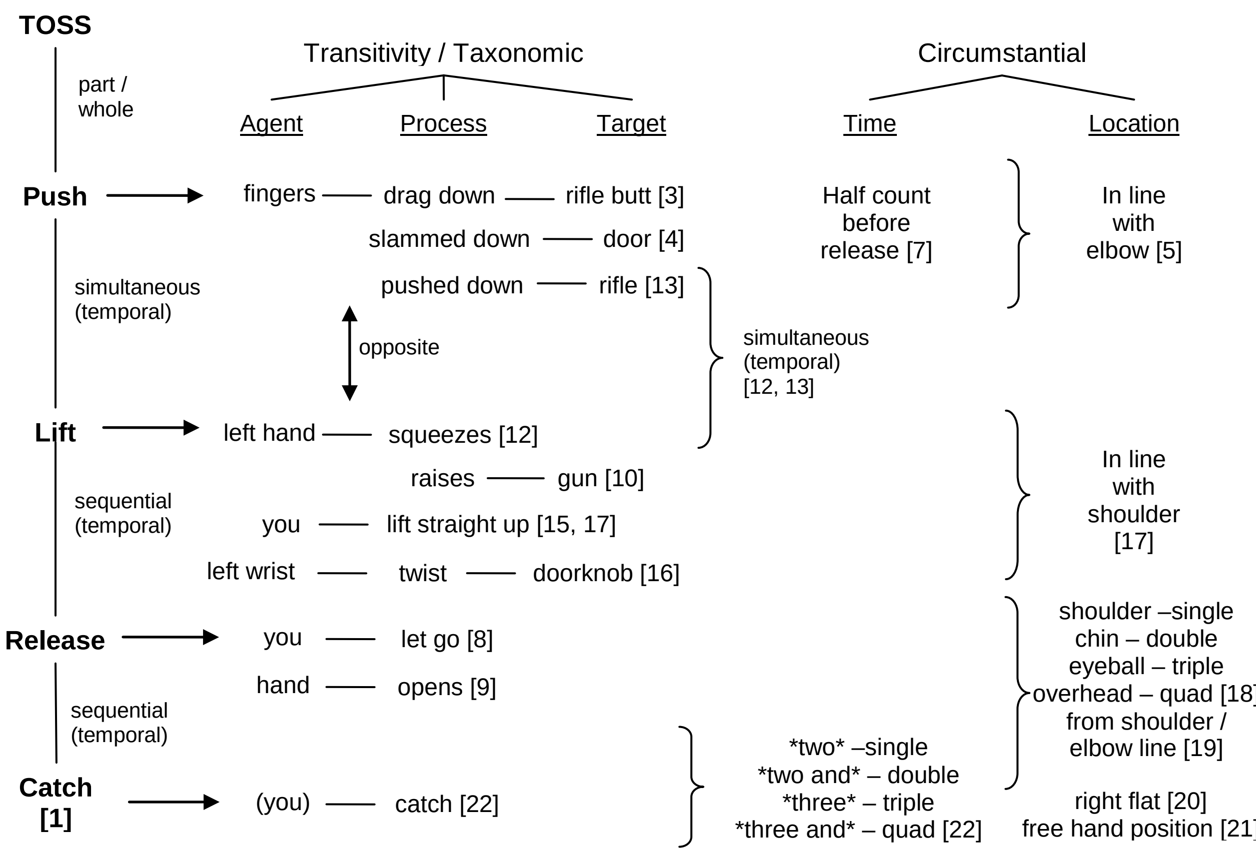


Figure 7. Thematic pattern for lexical concept of “toss”

These linguistic features of nominalization and condensation share some similarity with science, and this is where I agree with Brown and Kloser's (2007, p.291) finding that the "discourse of baseball, much like that of science, include complex conceptual, symbolic, and linguistic features". However, I do not agree with their optimistic inference that students could learn physics through the discourse of baseball. This is because it is not so simple to replace words from baseball or colorguard discourse with related words from physics discourse without losing their specific meanings. For instance, consider the transitivity relationship (i.e., agent-process-target) of *push* and *lift* as shown in Figure 7. *Push* is constituted by the material processes (Halliday, 1994) of "drag down [3]", "slam straight down [4]", and "pushed down [13]", while *lift* consists of "raises [10]" and "straight up [15,17]." Concomitantly, looking at the agent and target positions of the clauses, there are "right fingers [3]" and "rifle butt [3]" for *push* and "left hand [12]" and "barrel [14]" for *lift*. Thus, this binary set of down/up, right/left, and butt/barrel defines the oppositional semantic relationship between *push* and *lift* in colorguard discourse. Furthermore, there is also a temporal relationship between *push* and *lift* such that one follows directly after the other as was implied by the sequential bullet points in the text.

Now, turning to physics discourse, the words *push* and *lift* are also common lexical words found in mechanics. However, within the thematic patterns in physics, they form a different semantic relationship with each other. Both words are closely related to the generalized lexical concept of *force*, and they are commonly defined in a pre-college physics textbook (e.g., Zitzewitz, et al., 2005) as:

> *Force* is a *push* or pull exerted on an object that causes a change in motion. It has both direction and magnitude and may be a contact or a field force.
>
> *Lift* is a mechanical force generated by a solid object moving through a fluid.

From these two textbook definitions, a *force* is a superordinate lexical concept that subsumes both *push* and *lift*. It can also be shown (through more thematic patterns) that *lift* as used in fluid dynamics (a subfield of physics) can be considered a type of *push*. Thus, the set/subset relationship of *force* – *push* – *lift* in physics discourse is different than from the oppositional and temporal relationship of *push* – *lift* in colorguard discourse. The first relationship focuses on the generalizibility feature of *push* and *lift* as a common phenomenon of force, while the other emphasizes the elaborated bodily coordination of *push* and *lift* in relation to a particular human action.

In this sense, the similar wordings are not replaceable from one context to another. If the terms *push* and *lift* in colorguard were simply replaced with the ubiquitous physics term *force*, the elaborated oppositional, temporal, and situated meanings involved in those actions would be lost. As I will show later and in the next chapter, this reductionist tendency was precisely what happened during several exchanges I had with Lucy and Evelyn as I was perceiving the natural event they described with a different semantic lens. In other words, the semantic system (consisting of lexicon and grammar) in a discourse can greatly affect the way we name and categorize our experiences and perception of events.

Spatial & Temporal System.

Besides these taxonomic and transitivity relationships in the semantic system, there is also a spatial and temporal system that is peculiar to each sports discourse. In colorguard, the spatial frame of reference is always situated according to the tosser's body, and there are linguistic resources for indicating both direction and position according to this frame of reference. In the earlier excerpt, during the execution of *push*, "straight down" is understood with reference to "*lined up* with elbow" in line [5], and during *lift*, "straight up" is "*in line* with your shoulder [17]." These references for direction are always necessary in order to define what is "up", "down", "front", "forward", "back", and "flat"; words that appear frequently in the colorguard text. For position, the tosser's body parts are used for reference, such as "at *shoulder* for single, at *chin* for double, *eyeball* for triple, and barely *overhead* for quad [18]", and "*wrists* below *elbows* [20]." Sometimes, the rifle parts are also used like "*butt* of the rifle [3]" and "at the *grip* and *tip* [20]." Collectively, these spatial relationships are important for colorguards to coordinate their hands and bodily movements and synchronize with other tossers in making a uniform and harmonized performance.

Other sports also have their own unique spatial references for direction and position. In baseball for example, pitchers and batters take their frames of reference from the spatial positions of the baseball field, for example, the pitcher's plate, mound, catcher, first base, third base, and home plate are used to orientate the pitcher on where to face and how to stand at different stages of the pitch (e.g., wind up position, pivot). In some sports like football, the game requirement is such that a more precise spatial system is needed. This gives rise to a measurement system (in yards), the marking of equal intervals of stripes on the field, and the usage of lexicon in reference to this measurement system (e.g., first down, end zone).

For a temporal system, most team sports have developed their own system of dividing time within the duration of a match (e.g., half-time, quarters, extended time) and use modern day clocks to keep track of the passage of time. In colorguard, there is a very unique way of organizing and telling time during a toss, and it relies on verbal counting according to a certain tempo and a system of eighths. This type of counting is necessary presumably because it is not possible for colorguards to look at a stopwatch in the midst of doing a toss, and they need to have a coordinated sense of timing to execute their synchronized moves. How such counting is carried out was first seen in line [7] of excerpt 1, where the *push* is executed on the count of "AND" and release occurred at "one", which is half a count later. In the next line [9], the count "one" can be further subdivided into "re-LEASE", where "LEASE" is a one-quarter count for the hand to open. In line [22], there is further instruction on catching a single on "two", a double on "two and", a triple on "three", and a quad on "three and."

According to Simmons's (2010) counting system, it would take 1 count after "LEASE" to catch a single, 1.5 for double, 2 for triple, and 2.5 for quad. During a discussion with Lucy and Evelyn as they were making a connection to physics, they used this counting system to gauge the time duration for a tossed rifle to go up in the air and back during a quad (see next chapter). They needed to estimate this duration because they wanted to make some calculations for their text assignment. Intuitively, they both took each count to be equivalent to one second. According to their counting system (which differs from Simmons by a factor of 2), it would take 5 seconds between release and catch for a quad. However, based on my own measurement and calculation[5], I found that the time taken for the rifle tosses do not tally with the time suggested by their counting system. On average, I found the time taken to be 0.70 s, 0.90 s, 1.15 s, 1.40 s, and 1.80 s

[5] I used 3 different videos demonstrating rifle tosses and a video editing software for my measurement. The editing software allowed me to look at the tosser's movement frame by frame (at 30 fps) and calculate the time between the lift and catch. I then took the average from 3 different videos. Based on the frame rate of 30 fps, I calculated the margin of error to be about ±0.05 s.

for double, triple, quad, fifth, and sixth respectively. Not only was the students' estimation off, but it is also not possible for the consecutive time interval between each rotation to be equally divided, that is at half a count or 0.5 s consistently. Instead, as my calculation shows, the time interval increases as the number of rotations increases. This relationship is also consistent with the laws of physics. What this means is that Lucy's and Evelyn's estimation was off not because of any human error and inconsistency typically involved in estimating time with verbal counting (although this does happen), but because the colorguard temporal counting system itself is fundamentally incompatible with the division of time in seconds.

Yet in the first place, why should the two temporal systems be consistent? As I mentioned, the colorguard counting system was developed to help colorguards manage their bodily movement and coordination, and not to precisely tell the passage of time. Neither was the system developed to find out how long (in seconds) it would take for a rifle to be in the air for the various tosses, which is the type of question only a physicist, mathematician, or engineer would be interested to ask. Instead, the colorguard temporal system is actually synchronized with the tempo of the particular music used during a performance.

The organization of space and time is also central to physics and many other natural sciences, and each has developed its own peculiar systems. In physics, there are very elaborated systems of spatiality and temporality, of which one such system (non-relativistic Cartesian coordinate system) is explicitly taught at the beginning of most high school classes. According to the students' textbook , the "*coordinate system* tells you the location of the zero point of the *variable* you are studying and the direction in which the values of the variable increase. The *origin* is the point at which both variables have the value zero." (Zitzewitz, et al., 2005, p. 34, italics added). Thus, like sports discourse, there are semiotic resources within physics discourse to explicitly indicate both direction and position with respect to a particular frame of reference. However, unlike sports discourses, the object that is defined with respect to this coordinate system is a general "variable", and not a concrete rifle, baseball, or football. Furthermore, the spatial position of this object always takes reference from a single fixed point (i.e., origin) unlike the relational reference points used in sports. Such a coordinate system meant to be applied in every event involving motion is one of the universalizing features of physics discourse.

Physics also has a standardized temporal system that organizes and quantifies our experiences with time, or the duration between sequence of events. This system uses the second as the basic unit of measurement. For centuries, the definition of a second, based on either the Earth's rotational period (i.e., 1/86400 of a solar day) or orbital period around the Sun (i.e., 1/31,556,925 of a solar year), has been revised several times. In modern times, as the Earth's motion has been found to be irregular, the measurement of time based on an atomic clock was used. Today's standard SI second, adopted in 1967, is defined as the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the Caesium 133 atom. This SI second is the current standard used by scientists and is taught at the beginning of a typical physics textbook. Because the SI standard of time using an atomic clock is independent from the Earth's motion, the SI second does not match precisely with the standards of second intended for civil and astronomical uses (obtained by dividing the mean solar day), such as the Greenwich Mean Time (GMT). For this reason, "leap seconds", as determined by an international professional body, has to be added occasionally to adjust and calibrate the two sets of time standard. Therefore, this illustrates that the temporal system used in physics discourse is not a natural and universal scale that we have often taken for granted, but is one rife with socio-historical and technological developments catered for specific purposes. In this sense, it is a unique temporal system developed to quantify our experiences with temporal events according to specific interests in framing those experiences, just like the temporal counting system used by colorguards during their tosses.

Visual System.

Discourses also use different visual systems to frame different phenomena of interest. In sports and automobile texts, vivid real-life photographs of athletes and cars in different postures and angles often occupy a significant portion of a text. On average, there are 3.7 photographs for every sports and automobile article (printed or online) brought by the students. Although there are many reasons why these photographs were shot and used, the most common reason was to entice or inspire awe among readers. Two exemplars from *Thrasher* and *MotorTrend* magazines (contributed by Ron and Hanks) are shown respectively in Figures 8 and 9. For these photographs, there is little to no explicit references between them and the article's written text so much so that one does not need to look at the visuals to understand the text's content (or presentational meanings), and vice versa.

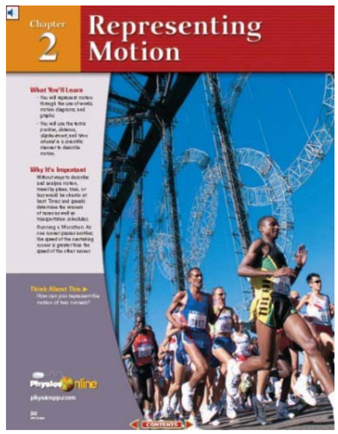
Figure 8. A photograph of a skateboarder from an article in *Thrasher* magazine.

Figure 9. A photograph of a Ferrari Scuderia from an article in *MotorTrend*.

In Kress and van Leeuwen's (1996) visual framework, these photographs, which portray objects as observed in reality from certain oblique angles and in full saturated color, are considered naturalistic and perspectival. Perspectival images are those that are created with a certain angle such that the viewer can only see the represented object from a particular point of view. According to Kress and van Leeuwen, the creator (e.g., painter, photographer) using this perspectival system is able to express subjective attitudes toward a represented object and at the same time, impose those attitudes on the viewers by framing the way they see that object in the image. For both Figures 8 and 9, the perspective was chosen from a low-angle close-shot of the represented objects. In Figure 8, the particular angle invokes a sense of awe at the skateboarder's stunt (as opposed to a lateral long-shot photograph taken from the spectator stand). In Figure 9, the same low-angle and slanted perspective subjects the viewers to "look up to" the Ferrari Scuderia 430 with a sense of fascination and desire.

For the *MotorTrend* article, this visual stance is further reinforced by the frequent use of positive appraisal words (an orientational meaning dimension) in the written text such as "Formula 1-inspired", "patent-pending", and "enhancing the F430." Together with the appeal of symbolic pop icons such as the Ferrari brand (see chapter 4 on popular cultural funds), this creates an attraction that draws many car enthusiasts like Hank to "want to buy all these cars." Therefore, such conscious semiotic designs (in terms of camera composition, photo editing, and selection of multiple shots) are aimed at positioning its audience toward a certain orientational stance. In reference to their orientational function, I call these visuals *affective photographs*.

Compared with school-based texts, it is interesting that affective photographs are also employed in the textbook. This is not surprising given that the use of visual images is becoming more prominent and pervasive in contemporary textbooks (Kress, et al., 2001; Veel, 1998). However, there is a notable distinction in that affective photographs are only found at the beginning of a chapter or unit, and are gradually replaced by more abstract visuals as the chapter or unit develops. For example, Figure 10 and 11 show two photographs found at the beginning of chapter 2 and 3 respectively. Note the similar use of oblique angle and close-shot of athletes and racing cars in comparison with Figure 8 and 9. Like most affective photographs, the purpose of these beginning pages is to engage the readers. To some students, this seemed to be effective as the use of sports and automobile photographs aligned with their interests (chapter 4, 5, 9, 10, and 11 include appealing photographs of a soccer player, rock climber, baseball batter, biker, and skier respectively). To others, this had little effect as these students hardly paid attention to the beginning of each chapter, which as Lucy saw it, "is pointless because they're trying to get [students] interested, and it's usually like useless."



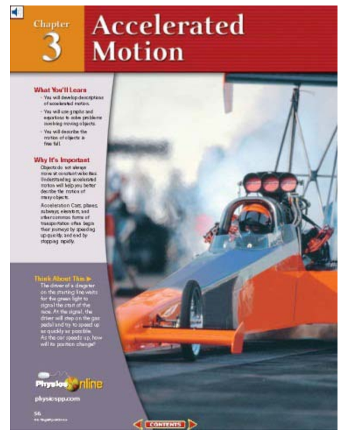


Figure 10 and 11. Beginning pages of chapter 2 and 3 respectively.

Besides the few affective photographs, the majority of photographs used in the textbook belong to a type I call *transitivity photograph*. Transitivity photographs play a bigger role in the co-construction of the text's main presentational meaning. In contrast to affective photographs, they are shot without an oblique angle; that is, either perpendicularly frontal or literal. This is because their usage is meant to be less orientational. By contrast, its presentational meaning stands out as the images narrate some actional and temporal processes of a particular motion (Kress & van Leeuwen, 1996). This visual structure is analogous to the *transitivity* semantic relationship found in a linguistic system (agent-process-target).[6]

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[6] These visual systems are similarly observed when the medium used is a video instead of a magazine, online article, or textbook. A video is essentially a long series of still photographs in quick time successions and coupled with a voice-over narration. Extending this visual analysis to the use of videos is important because videos occupy a significant portion of the students' choice texts. However, in the interest of space, I will not illustrate this analysis.

One of the most prominent transitivity photographs used in the physics textbook is a type of edited photograph called *motion diagram,* such as the one shown in Figure 12. A motion diagram is “a series of images showing the positions of a moving object at equal time intervals (Zitzewitz, et al., 2005, p. 33). The textbook considers motion diagrams part of a visual system “useful in determining when an object is at a particular place and time.” (p. 32). Motion diagrams are introduced at the very beginning of mechanics, thus signifying its foundational use as a tool to visually represent motion. However, motion diagrams are mainly pedagogic devices that scaffold the students toward a much more complex visual system involving dots, arrows, and lines, which is the system used by scientists.

Figure 12. An important transitivity photograph taken from the textbook.

The textbook does this scaffolding by replacing the object depicted in motion diagram with “a series of single points.” As the textbook explains, this is useful because “keeping track of the motion of the runner [as depicted in Figure 12] is easier if you *disregard* the movement of the arms and legs, and instead concentrate on a single point at the center of her body” (Zitzewitz, et al., 2005, p. 33; *italics* added). Once this “disregarding” process is carried out (a form of objectification), the next step involves introducing a coordinate system and several lexical concepts like *origin*, *vector*, *displacement*, and *velocity* (see earlier analysis on spatial system). Following that, several standardized visual conventions are also introduced, such as:

(a) "the length of a vector [drawn] should be proportional to the magnitude of the quantity being measured" (p. 35)
(b) "always draw the force arrows pointing away from [never toward] the particle" (p.89)
(c) "use a protractor to draw the vectors at the correct angles" for two-dimensional motions (p.120)

Thus, through this (a) objectification, (b) spatial coordinate system, and (c) visual conventions, a transition takes place from the use of naturalistic photographs to the development and use of a pictorial representational system called a *free-body diagram*. For mechanics, a free-body diagram is the quintessential visual representation used by mechanical physicists and engineers in their problem-solving practices. It is also the most important visual tool so much so that Brad and I kept insisting that the students always draw a free-body diagram in their work.

The transition from naturalistic photographs (which are common in the students' texts) to schematic diagrams is one of the most salient visual features in the textbook. This transition takes place through three stages, with each stage signaling a higher level of decontextualization and modal value (approximation to truth). An exemplar can be seen from Figure 12 (shown earlier) transiting to the following Figure 13 and 14. Figure 13 is a hand-drawn illustration that aims to reproduce what was shown in Figure 12. The transition from a photograph depicting realism in what we see in our everyday world to a drawn illustration signals the first stage of decontextualization from a specific realm (applied only to where the photograph was taken) to a universal one (since an illustration can always be produced anywhere). The second stage from Figure 13 to 14 is where the runner's body is "disregarded", and reduced to single points and arrows in the objectification process. The third stage of decontextualization involves removing the background and the horizontal-spatial scale in Figure 14 altogether and what remains are just the schematic free-body diagrams consisting of dots and arrows (not shown here). This adds yet another layer of modal value as schematic diagrams depict an "objective" stance (Kress & van Leeuwan, 1996), which distances itself from the viewer and gives a sense of universality that the events and actions as represented (from *moving* objects to *motion* to *displacement* vectors) are true independent of the involvement of any human subject.

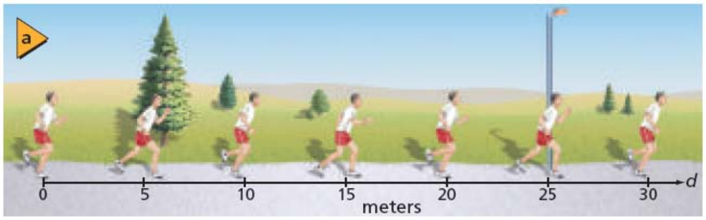

Figure 13. A hand-drawn illustration that reproduces Figure 12.

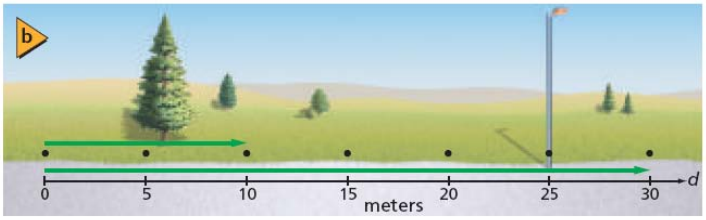

Figure 14. A schematic diagram abstracted from Figure 13.

Table 6 shows the transition in terms of the frequency of the three stages of visual representations (excluding graphs) from chapter 2 to chapter 5 of the textbook. From the table, naturalist photographs (including both affective and transitivity) are the most common (50%) in the beginning chapter but drop rapidly in later chapters until a mere

8% in chapter 5. Conversely, schematic diagrams gradually increase from 27% in chapter 2 to an astounding 64% in chapter 5. Thus, in a matter of weeks from learning chapter 2 to 5, the students were taught to “see” events of moving objects not as concrete and specific things, but as abstract dots and arrows of motions that are universally applicable in every circumstance. Through this transition and explicit teaching of the abstract visual system, this is how school physics discourse frames the phenomena of moving events in terms of how they ought to be seen.

Table 6. *Frequency of Types of Visual Representations used in Chapter 2 to 5*

	Chapter			
	2	**3**	**4**	**5**
Naturalistic Photographs	11 (50%)	3 (14%)	6 (17%)	2 (8%)
Free-hand Illustrations	5 (23%)	9 (43%)	15 (42%)	7 (28%)
Schematic Diagrams	6 (27%)	9 (43%)	15 (42%)	16 (64%)
Total Visuals	22	21	36	25

Intertextual System.

The last system I want to explicate is that of intertextuality. In contrast to the system of semantic relationships, spatial referencing, temporal pacing, and visual perspectives, this is a system of *texts* themselves (see Lemke, 1995). That is, within a particular discourse, what are the set of important or valued texts, what texts are frequently referenced or alluded to, and what other texts are typically juxtaposed as a person interprets or produces a text? As reviewed in chapter 2, there are two types of intertextuality: manifest and constitutive intertextuality (Fairclough, 1992). In terms of manifest intertextuality, the textbook as an inclusive collection of chapters is quite explicit about where specific chapters are overtly drawn upon within a particular chapter. A textbook also typically has resources such as glossary, index, vocabulary lists, and end-of-chapter study guides to help students make intertextual connections within the book. Such organizational structure and resources point to the cumulative nature of scientific discourse and the linearly methodological approach to aid students build that discourse. By comparison, the system of manifest intertextuality is less obvious in the students' texts, particularly in magazines and TV programs. For instance, an article of a magazine issue or a documentary episode (e.g., *Sport Science*, *Mythbuster*) rarely makes explicit reference to another issue or episode, unlike the citational resources that scientists use in their journal publication.

However, constitutive intertextuality plays a bigger role in the students' out-of-school discourses. This form of intertextuality focuses on the intangible elements of discourses that make up a primary text, both during its production (by author) and interpretation (by reader). These elements include text-types and voices, which are not easily traced directly to sources, but are evidently drawn upon during a text's production and interpretation. I will show an exemplar of how constitutive intertextuality was present in Hank's reading of *MotorTrend*, and the mutually constitutive relationship between automobile writers and readers in the production and interpretation of automobile texts. The following interview excerpt occurred when I was asking Hank to explain a passage from his *MotorTrend* text. Part of my interview was to assess how much he understood the content of the article:

Interviewer: In this sentence, what does 503 horse and 651 horse mean?

Hank: Horsepower. It’s the horsepower of the car. And they are comparing this car to a previous model of Ferrari.

Interviewer: Do you know what is horsepower?
Hank: Yah, I know. It's back when they have carriages. One horsepower is equivalent to one horse. I don't know how the conversion actually works out but that's all I knew about that.

Interviewer: When you are comparing the 503 [horse] and the 651, what does that comparison tells you? (points to a particular paragraph of the text)
Hank: (reads text silently) Um.. It talks about the horse, but it says.. And also the.. *0 to 60 is a big one, they always use that in every article*, the speed, the acceleration... The more horse the more.. power the car has, the faster it can go. And.. the 0 to 60 is just a timing of how fast it can accelerate.

As I have argued under semantic system, every discourse has its own specialized lexicon and thematic patterns among its lexical words. But automobile discourse is particularly notorious for its heavy usage of technical terms. In the passage that I asked Hank to read and explain, there were terms like “horse”, “torque”, “0-to-60”, “pushrod-actuated suspension”, “aero-gear”, “V-12”, “carbon fiber”, “traction control”, “downforce”, “aerodynamic”, “drag coefficient”, and “lift coefficient.” (Some of these overlap with physics vocabularies.) Although these terms were never defined nor was there a glossary section similar to that of a textbook (i.e., lack of manifest intertextuality), Hank recognized and understood most of their usages. What was most interesting came from his recognition of 0-to-60 as “a big one they always use that in every article.” This shows that Hank read this particular article in juxtaposition against the backdrop of an automobile text-type, which is constituted by other automobile articles he had come across and formed part of his repertoire of automobile knowledge. This allowed him to identify 0-to-60 as “a big one” and also understand its usage as “a timing of how fast [a car] can accelerate." Conversely, producers of automobile magazines are well aware that the majority of their readers are car enthusiasts like Hank who have been reading car texts or engaged in car talk for quite some time, and are thus expected to know the meaning of certain common technical terms, like 0-to-60. Thus, there is never a need to include such definitions in cars magazines.

Constitutive intertextuality is not just about having some prior knowledge to inform one's conceptual understanding of a text. It also involves a certain preferred stance of reading/writing one text against other texts, and this is also linked to the notions of *voices* and *habitus* I talked about in the last chapter. For instance, the use of 0-to-60, which is the time taken (in seconds) for a car to accelerate from rest to 60 mph, is just one of many preferred ways of measuring acceleration. The choice of 60 mph is quite obviously linked to the speed limit of major roads. Outside the U.S. and U.K., it is more common to use 0-to-100 km/h instead. However, in physics discourse, acceleration is typically measured in its SI units of m/s^2 and never as a unit of time. But in the case of automobile discourse, it is quite easy to understand why 0-to-60 or 0-to-100 is preferred instead of m/s^2. First, it is rare for any car to maintain a constant acceleration during its pickup. Second, it is pointless for drivers to know about a car's acceleration in m/s^2 as they are more concerned about how long it takes for the car to achieve its full legal speed from a stop. Thus, this example shows that the differences in measurement units are not just a matter of conventions, but are also related to different preferences situated in specific contexts. It is also another good example of the different spatial-temporal systems used in different discourses.

Another revealing example can be seen from the type of knowledge that Hank had about the lexical concepts of "horsepower" and "torque." (These are also concepts used in physics discourse, although power as measured in Watts is typically used instead of horsepower.) In the earlier excerpt, Hank demonstrated a knowledge of horsepower as a measurement of a car's performance in comparison with "one horse" as well as its historical origin from "carriages." However, he also acknowledged that was "all [he] knew about" and he did not really understand "how the conversion actually works out." At a later point, I asked him if he knew what a "torque" is, and his reply was:

> I don't know exactly, once again with the calculator or anything. But the more torque is the.. the more power it has. But it's not necessary speed. Its.. a SUV would have more torque than Ferrari here because.. it can pull more. It can pull bigger things, a boat, when a Ferrari couldn't even pull you know a tiny little thing right?

Both this and the last response show that Hank did not quite know the *formal mathematical* relationship between torque, power, and speed, as reflected in the phrases "don't know the conversion" and "with the calculator." However, he clearly understood their *functional* relationship: that a SUV with more torque "can pull bigger things." He also mentioned later that "trucks and everything are made for torque" while the Ferrari, which "couldn't even pull a tiny little thing", is "meant for speed." Thus, Hank's inability to articulate the mathematical relationship between torque, power, and speed, but ability to explain real-world application of these ideas illustrates a major contrast between the kind of knowledge valued between the two discourses. Within school physics discourse, the mathematical relationship (power = torque x angular speed) is explicitly taught and emphasized, while the application in cars less so. Conversely for automobile discourse, Hank's responses were an indication that the system of texts that he had habitually been reading seldom emphasizes such formal definitions and relationships.

Based on this analysis, a few things were learned about the system of constitutive intertextuality within and across discourses. First, in the production of a text, such as the Ferrari Scuderia 430 article, car magazine authors habitually draw upon their repertoire of automobile text-type formed over time through their engagement with automobile texts. As shown in chapter 4, this can be explained by the traversal and circulation of text-experiences within the community network of automobile writers, fans, enthusiasts, engineers, and dealers. Thus, this gives rise to the development of certain prototypical characteristics of car talk (e.g., comparison of horsepower between cars) and a devoid of others (e.g., formal definitions and relationships). Likewise, in the production of school science texts, it would be strange to see the inclusion of car reviews, stories, manga, or pop music, which belong to other text-types and discourses.

Second, in the interpretation of text, readers draw upon a set of related texts from their repertoire (usually within one's preferred discourse or habitus) to evaluate what they are reading. Thus, it was very "natural" and easy for Hank to expect certain ways of reporting a car's performance in his article such as the use of "0-to-60" or "horsepower". However, for someone who is not exposed to automobile text-type or is more familiar with a contrasting set of texts, he or she may (a) not understand the article, (b) raise questions about its appropriate use of terms or argumentation, or (c) appreciate less the type of knowledge (e.g., real-world application) valued in the discourse. This particular aspect of constitutive intertextuality, which Ivanic (2004) calls "habitual intertextuality" that links to a person's socially structured and structuring habitus (Bourdieu, 1984), is an important process for understanding how phenomena are framed within a discourse. It is also a powerful illustration that text interpretation is not simply about having some prior knowledge to aid conceptual understanding, but also involves habitual preferences and stances of reading one text against other texts.

The Framing of Contrasting Phenomena.

To sum up, the semantic system forms the way we label and categorize our experiences and perception of events through a web of semantic relationships. The spatial-temporal system shapes how we index and quantify our experiences with space and time. The visual system influences the way we "view" reality and notice the salient aspects of our experiences. And finally, intertextual system relates (overtly or habitually) a present text or event with a network of associated texts, text-type, and conventions that authors and readers have encountered over time in their text-experience trajectories.

With all these four systems in mind, I now return to the question of how each discourse constructs different phenomena from a common event of interest. As an illustration, let us consider a vertical rifle toss as an event and examine how colorguard and school physics discourses typically frame the phenomenon of this event through their respective systems. For school physics discourse, consider the following two questions from the textbook:

Q1. You toss a ball up in the air. Draw a free-body diagram for the ball while it is still moving upward. Identify any forces acting on the ball. (Section 4.3, p. 104)

Q2. A student trying out for the football team kicks the football straight up in the air. The ball hits him on the way back. If it took 3.0 s from the time when the student punted the ball until he gets hit by the ball, what was the football's initial velocity? (Section 3.3, p. 75)

Although these questions are not directly related to colorguard, they can easily be transformed into colorguard-related questions. A common approach used among physics educators when they need to generate new questions for student assessment is to replace the objects and numbers in existing questions with a new set of objects and numbers, coupled with some minor rephrasing. Thus, the "ball" and "football" in Q1 and Q2 could very well be a colorguard rifle, or even a soccer ball, baseball, stone, or cheerleader flyer. If the questions were about horizontal motion, then the object could also be a bowling ball, runner, skater, bicycle, car, boat, or train. Similarly, all the human agents initiating the motion (e.g., "you", "student") are also replaceable. Of course, this replacement must be carried out within realistic physical limits; so anything heavier than a cheerleader flyer (about 50 kg or 110 pounds) will rarely be thrown up, and likewise the time for the flyer to come down will tend to be shorter than 1 second. In many cases, the context for a question can also be totally ignored by replacing all context-specific concrete objects with just the generic word "object", "body", or "particle."

I chose these two questions because they are representative of two key stages of a colorguard toss: Q1 for the bodily action during the *lift*[7], and Q2 from the time of *release* to *catch* (see excerpt 1). However, there are many semantic differences between the above two questions and excerpt 1 in terms of what are being emphasized and valued. Colorguard discourse foregrounds the human element (i.e., tosser) and the elaborated embodied actions undertaken in the *push-lift-release-catch* sequence. It is more

[7] The rotational movement of the rifle is bracketed for this analysis. This is possible because vertical and rotational motions are independent of each other, and Lucy and Evelyn were also advised to ignore the rotational motion as it was not beyond the syllabus. Nonetheless, had the rotational motion been considered, the analysis would remain the same in that the rotational motion will be replaced by the vectors of torque and angular velocity in physics.

concerned with the bodily coordination of the *push* and *lift*, the spatial position and tempo of *release*, whether the *release* is straight or *rainbow over*, and when and how to do the *catch*. In school physics discourse, the humans and their actions (e.g., “toss”, “kicks”, “punted”) are generic and do not change the meaning of the questions. Incidentally, while the word “toss” used in Q1 is devoid of meaning, the same word is an elaborated lexical concept for colorguard discourse as was shown in Figure 7.

Instead of emphasizing humans, school physics discourse assigns agency to the objects so that the “[ball] *is* still moving upward” (Q1) and “the ball *hits* him” (Q2). In addition, the objects are also given abstract constructs as part of their intrinsic properties; for example, in “*football’s* initial velocity” (Q2), the phrase indicates that the object (football) possesses a property called “velocity”. In short, the phenomenon framed semantically in colorguard discourse is one about the tosser’s elaborated bodily movement with and actions on a rifle, while school physics discourse frames a phenomenon of a moving object that has certain abstract and unseen properties (e.g., forces, mass, velocity, acceleration).

During the problem solution process, students were always encouraged (sometimes mandated) to include a visual diagram to aid their mental thinking. In fact, Q1 was explicit in this requirement to “draw a free-body diagram.” This highlights part of the intertextual system in school physics discourse where students were taught and conditioned to overtly juxtapose a prior visual-text (i.e., free-body diagram) with the current problem-text (e.g., Q1, Q2). In the visual system of a free-body diagram, any concrete object becomes irrelevant as it is “disregarded” and reduced to a single point with arrows (vectors) representing the object’s properties. In this process, as the semantic system foregrounds the moving object and backgrounds the human agent, the visual system further shifts the focus from the object's motion to just motion itself as represented visually by the vectors of force, acceleration, velocity, and displacement. At the same time, a spatial-temporal coordinate system is also juxtaposed (part of habitual intertextuality) so as to assign numerical values and polarity to the vectors. Typically, this is set up so that the origin aligns with the floor or at the point where the object is released. Once this is completed, a universal set of laws and equations can then be applied for the solution, and whether the object is a rifle, flag, cheerleader, ball, or stone becomes redundant.

Conversely, the phenomenon framed by the spatial-temporal and visual system in colorguard discourse is one that emphasizes the synchronization and aesthetic aspects of the toss. First, the spatial referencing system frames the tossing phenomenon with respect to the tosser's body rather than a fixed linear coordinate system, while the temporal counting system synchronizes with the tempo of the music in a performance and does not align with the equally divided system of seconds. Visually, colorguard stresses the gracefulness and synchronization of the movement, the design and color of the dress code, and the luster of the rifles; all of which are "disregarded" in a free-body diagram. This visual emphasis is also reinforced by the predominant use of affective photographs within the system of text-types in colorguard (mostly websites and videos). Another source of text-type that is typically juxtaposed with colorguard texts and events is music, which greatly affects the construal of phenomenon in a colorguard event in terms of the mood, tempo, and emotion (all part of the orientational meanings).

The assertion that discourses frame phenomena differently materialized in the classroom on several occasions as the teachers attempted to connect the students' interests to physics. An exemplar occurred during a group-discussion lesson that Brad and I planned to support the students in writing their text assignments. In this lesson, we divided the class into eight groups of four according to what we saw as more or less similar phenomena. For example, there was a group of football-soccer, car enthusiasts, track and field runners, and colorguard-cheerleading. Our rationale for this grouping was that with common phenomena within each group, there would be more collaboration as the students discussed the following assigned questions:

1. What is the phenomenon in your interest area that you are exploring?
2. What physics concepts will you use to explain the phenomenon?

We expected that the colorguard-cheerleading group would be jointly discussing objects in "free-fall acceleration" (a physics concept taught in a particular chapter). In retrospect, Brad and I were looking at colorguard and cheerleading events from a school physics discourse, and consequently reduced those events to a common set of dots, vectors, and formulae. As it turned out, there was a low level of collaboration between the pairs of colorguards (Lucy, Evelyn) and cheerleaders (Naomi, Melanie). As I observed this lack of collaboration, I walked over to them with the intention to facilitate their discussion, and initiated the following conversation:

> Kenneth: Did you find anything common within your group?
> Lucy: We (*pointing to Evelyn and herself*) have some common stuffs but we have nothing in common with them.
>
> Kenneth: Do you know why you are lumped together in the same group?
> Melanie: = No
> Evelyn: = (inaudible)

Lucy: = (inaudible).. unlike the men sports, ours don't have a ball in it.
(*Naomi laughs*)

When I first talked to these four students, I was taken aback that they did not perceive any commonality within the group. Yet, they had a lot to comment on their grouping based on their instantaneous and simultaneous responses when I asked them to deduce why they were put together. Lucy’s deduction that the grouping was done along a sexist sports division was particularly striking, and highlights an important ideological conflict of masculine hegemony, which I will return to address shortly.

Later as I suggested to them that because colorguard and cheerleading threw things vertically into the air, they were “quite the same in terms of the physics”, it generated some energetic reactions among them. Their hesitations toward my suggestion included the differences between tossing things and people, the different ways of tossing and spinning, and the different interactions between the tossing agents and the tossed objects. However, throughout their objections, I consistently maintained that if they just looked at the applied forces, a generic object, and the effect of gravity, then they were “quite the same.” At that point in time, I did not realize they were constructing the phenomena from a very different perspective, and I was simply looking at it from a particular reductionist viewpoint from school physics discourse.

The disagreement expressed by these students had little to do with their conceptual understanding as they could understand the basis of my argument. Instead, it had more to do with a negative disposition of seeing their beloved and unique sport being simplified to just another common sport. Subsequently, the students’ objections faded away as my position, drawing from the authority of school physics discourse, remained firmly unchanged. Yet, their silence did not indicate they were in agreement. From the exchange structure in our conversation, it was likely they deferred to my authority as a physics teacher and the current curricular task of finding a common phenomenon among the group. Thus, this heteroglossic exchange between me (from a school physics discourse) and the four students (from their respective sports discourses) highlights the contrasting phenomena that were being constructed in our interaction, as well as an implicit power relation in the ideologies behind the in- and out-of-school discourses.

Phenomena of Electrical Human Body

In this section, I illustrate one more example of how another out-of-school discourse (creationism) frames an event involving the human body differently from that of school physics discourse. For the analysis, I compare two texts representative of each discourse. The first is Naomi's choice text from *answersingenesis.org* (see chapter 4 for how this text was embedded within and selected from her funds of knowledge). The article, entitled "Electrical Design in the Human Body" (henceforth *Electrical Design*), was published in the magazine *Creation*. It was written by Craig Savige (1999), who was an electrical engineer with a degree in Bible Theology. The second text is a section taken from a physics textbook (Cutnell & Johnson, 2009) used in Brad's AP Physics class. The heading of the textbook section is "Conduction of Electrical Signals in Neurons" (henceforth *Conduction*). When Brad first read Naomi's choice text *Electrical Design*, he immediately recognized the very similar content with *Conduction*. Subsequently, he made a copy of *Conduction* for Naomi so that she could explicitly compare this text with her choice text. Although both texts' content are similar (as Brad recognized), there are major differences in how that content was framed due to their contrasting semantic, spatial-temporal, visual, and intertextual systems.

I start by analyzing the intertextual system implicit in *Electrical Design*. Like most creation texts, *Electrical Design* assimilated two text-types in its production: the first is an exposition of certain "matter of facts" that replicates the voice of scientific text-type, and the other is one imbued with an argumentative and evaluative voice. (This kind of overt polyvocality, or multi-vocal assimilation, is also commonly found in environmental and popular science texts.) The following passage illustrates these two text-types as they are juxtaposed in two consecutive paragraphs:

Excerpt 2: Electrical Design (Craig Savige, 1999, p.44)

1. To gain a true comprehension of the complexity of this circuitry, [1]
we must understand that co-ordination between neurons is essential. [2]
The computations required for such co-ordination are enormous. [3]
'There may be from ten trillion to one hundred trillion synapses in the brain, and each one operates as a tiny calculator that tallies signals arriving as electrical pulses.' (Restak, 1984, pp. 34-35)[8]. [4]
Thus, messages to and from the brain are relayed, moving from one neuron to another. [5]

2. It is difficult to understand how anyone can believe that the nervous system, particularly the brain, could have been produced by evolutionary randomness and selection. [6]
We have barely touched on some of the electrical design present in the rest of the body. [7]
The truth is that scientists are always discovering more about its workings, [8]
since its complexity, which far surpasses anything produced by man, is nothing short of a miracle. [9]
Truly we can say with David, 'I will praise You, for I am fearfully and wonderfully made; Your works are marvelous and my soul knows it very well' (Psalm 139:14). [10]

[8] The actual citation in the original text follows Chicago style. To minimize confusion for the reader in the different styles, I have changed the original citation into APA style.

The first paragraph, especially from line [3] to [5], utilizes the semantic system of a scientific (neuroscience) discourse to construct the presentational meanings of lexical concepts such as neurons and synapses, and their interactions. It uses the same type of language to depict the interactions as impersonal, timeless, universal, and undisputed "facts." In this aspect, the language used is very similar to that of *Conduction*, and was a major factor prompting Naomi to comment that *Electrical Design* had "a lot of [science] information in it." This borrowing of a scientific voice is seen throughout *Electrical Design*, and signifies a deliberate incorporation of certain elements of scientific discourse into its own creationist discourse. In fact, in line [4], there was a direct quotation (a manifest intertextuality) from a book entitled *The Brain* written by a neuroscientist (Restak, 1984). This and three other citations (all from science textbooks) are likely a rhetorical means to support the legitimacy of *Electrical Design*. It is also a subtle way of constructing an opposition between this scientific voice and a religious one, which dominates the next paragraph of the text.

In the second paragraph, there is a notable shift in the semantic system in terms of the clausal participants. Instead of neurons and synapses, there are personal beings: "anyone" [6], "we" [7], "scientists" [8], "man" [9], the Psalmist "David", and "You" (God) [10]. There is also an emphasis toward orientational meaning as seen from the sharp increase in the number of appraisal words, such as "difficult" [6], "barely" [7], "always" [8], "far surpasses", "nothing short" [9], "truly", "praise", "fearfully/wonderfully", "marvelous", and "very well" [10]. Concomitantly, there is another direct quotation in line [10], but instead of a scientific text, it is a passage from the Bible. Thus, in these consecutive paragraphs, there are two contrasting semantic and intertextual systems in direct juxtaposition; one using the voice and authority of science to frame the nervous system "circuitry" [1] as a presentational factual phenomenon, while the other invoking the orientational elements and an expressive Biblical verse to frame the nervous system as a wonder that "is nothing short of a miracle" [9]. As I show next, this juxtaposition of the dual voices does not occur on equal terms. There is in fact a subtle message in the dominance of one voice (of miraculous design) over the other (of impersonal evolution).

To see how this dominance comes about, we need to consider the habitual intertextuality implicated for a reader like Naomi. In a broader picture, the author Savige did not write this article merely for the sake of explaining the electrical elements in the human body, and neither do its readers read it for that purpose alone. Instead, it is part of an intertextual chain that constitutes the larger heteroglossic conversation between evolution and creation. This is clearly seen in line [6] when Savige directly juxtaposed the "complexity" of the nervous system (established in the preceding paragraph) with the outcome of "evolutionary randomness and selection", and framed this juxtaposition with "it is difficult to understand how anyone can believe that… could have been produced by evolutionary randomness and selection." Furthermore, through the phrase "it is difficult to understand", Savige clearly demonstrates his stance (and persuades its reader to do likewise) toward the inconceivability of evolution in favor of the obviousness of a complex design. Through such a juxtaposition and orientational stance, the idea of evolution, which is a major lexical concept constructed within the discourse of biology, is thus subjugated in the discourse of creationism.

For most readers of *Electrical Design*, it is very likely they would at least know the basic idea of evolution. However, their stance toward its presentational meaning would depend on the backdrop of texts they bring (as part of their habitus) in interpreting evolution and the rest of *Electrical Design*. For Naomi, chapter 4 showed the backdrop of texts consisted of *The New Answers Book* (Ham, 2007b), *answersingenesis.org*, the discussions and videos shown during her Answers in Genesis class, and the Bible and all its supporting texts. Therefore, in Naomi's reading of *Electrical Design* and *Conduction*, it is not sufficient to just consider the interpretation of these specific texts alone, but also a larger set of texts garnered through her text-experience trajectories within her family and community funds of knowledge.

From this larger set of texts, further contrasts between the semantic, visual, and temporal systems in the different discourses can be observed. The temporal system is perhaps the most conflicting in terms of how each discourse frames the event of human life and existence. For science discourse, the temporal system based on radiometric dating and the linear extrapolation of existing data (e.g., fossil records, cosmic background radiation, red shift observations) establishes the phenomenon of an old Earth and Universe in billions of years. By contrast, the temporal system in creationist discourse relies on the account of Genesis and a literal interpretation to frame the phenomenon of a young Universe created in "six literal days." This temporal system is implicitly projected into *Electrical Design* to suggest the demarcation between the creation and the post-creation events of human existence. This is seen in several instances at the beginning of the article, such as "electricity and devices which harness it have been around *since the beginning of creation*" and "the Creator's understanding *prior to* man's electrical inventions" (Savige, 1999, p.43).

Visually, the images used in *The New Answers Book* and *Creation* magazines consist of a mixture of photographs and drawings, but few schematic diagrams. Like the diagrams used in science texts, these images do complement the presentational meaning of the main written text. However, they also have a prominent orientational dimension to engage readers in adopting a certain stance and attitude toward its content. The main visual used in *Electrical Design* is an exemplar of this feature. As shown in Figure 15, the series of three images in this visual complements two aspects of the presentational meaning in the written text: (a) the spatial distribution of charged ions across the membrane, and (b) the action potential due to a stimulus and its propagation down the nerve fiber. Comparing this with a diagram from *Conduction* in Figure 16, there is a close similarity in terms of the presentational meaning.

However, in terms of the orientational meaning, there are clear differences. First, the adoption of an oblique angle in Figure 15 suggests a more intimate author-viewer relationship that invites the viewers to be personally involved in the presentation of its content. This is also in alignment with the expressive and evaluative tone used in *Electrical Design*. On the other hand, the frontal view in Figure 16 depicts an "objective" stance and distances the viewer from its presentational "scientific" content. Second, the visual focus of the nerve fiber as a whole in Figure 15 (instead of the microscopic cell membrane in Figure 16) indicates a broader visual perspective, which aligns well with the focus of *Electrical Design* on the holistic human body, and indirectly on its design and creation. By contrast, the narrower view in Figure 16 showing only the cellular fluid, cell membrane, and charged ions is consistent with the focus in a physics textbook to explain the mechanical interaction of these impersonal objects (which are lexical concepts constructed within the discourse of biology). Thus, this visual contrast underscores the major differences between the framing in these two discourses.

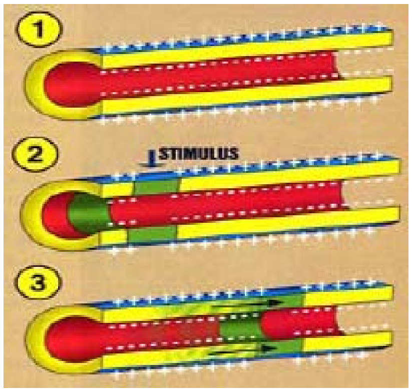

Figure 15. An illustration used in Electrical Design.

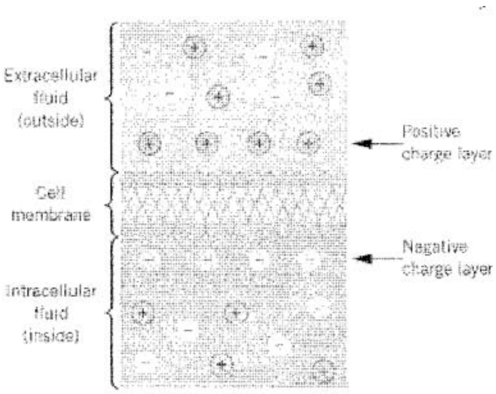

Figure 16. An illustration used in Conduction.

Therefore, this analysis explains how two texts of similar presentational content (relating to the natural event of signal transmission in the nervous system) can lead to the framing of different phenomena, particularly in the orientational aspect. For *Electrical Design* (with its accompanying intertexts), the phenomenon constructed is personal and directly involves the author and readers (as human beings). It invites them to evaluate themselves as the product of creation and a miraculous intelligent design, instead of a random evolutionary process – an issue overtly drawn into the conversation and subtly contested. The theme of a divine design is pervasive throughout the article and is even foregrounded in its title with the emphasis on "Design." On the other hand, *Conduction*, like most science texts, chooses to focus on the "objective" technicality of the subject matter. Thus, it frames the phenomenon as one that involves material interactions among inanimate lexical concepts of neurons and charges; as suggested by its nominalized title "*Conduction of Electrical Signals in Neurons*."

Although *Conduction* is specifically silent on evolution and human origin (it is after all a physics chapter on electricity), intertextually speaking, it cannot remain detached from this issue. This is not only due to the interconnectedness among the various science disciplines, but also because students will inevitably juxtapose this text and interpret its meaning against a network of other texts (as habitual intertextuality). For some students, the habitual intertextuality from a creationist and/or religious discourse could lead to their adoption of certain stances (e.g., rejection, resistance, alienation) toward the science content being presented to them in school. An example could be seen in Naomi's resistance to evolution and her dilemma in whether to pursue her college education in a secular university or a Christian college.

Ideological Conflicts

An ideology is the underlying system of beliefs that justifies and naturalizes the way discourses operate in order to maintain, support, or contest certain political, economic, and social conditions. All discourses, which are ways of framing how natural and human events ought to be seen from viewpoints within particular communities, are inherently ideological (Gee, 1990). As various communities contest with one another over public resources and privileges, discourses are also deeply political (Fairclough, 1992; Lemke, 1995). In this last section, I briefly discuss how the contrasts between the various phenomena shown earlier are also partly a manifestation of the ideological conflicts between different social groups of people and their underlying interests and values.

One of the most frequently recurring motifs as I explored the various phenomena is the tension between reductionism and objectification on the one hand and personification and idolization on the other. In science and school science discourses, the framing of events as generalizable phenomena governed by a reductionist set of laws and principles is part of the positivist ideology of establishing objective, value-free, and universal truths. This ideology is perhaps most prominent in physics due to the perception of its pinnacle in the so-called "unity of science" (followed by chemistry, biology, "hard" sciences, and "soft" social sciences), which seeks to apply scientific laws universally on all levels of natural and human organization (Harding, 1986). Although positivism originated from the empiricist traditions in science and a group of philosophers of science (i.e., Vienna Circle), it later became a crucial instrument for a technocratic elite seeking to control policy decisions and public opinions by appealing to the general findings of experts (Lemke, 1990, 1995). Re-contextualized in school curriculum, this ideology promotes an authoritative view of science that favors observable and generalizable facts and disdains personalization, emotions, and subjective experiences.

On the other hand, sports ideology promotes the values of individualism, hero worshipping, wining at all cost, and glorification of commercialism. According to critical theories of sports, modern sports are important popular cultural practices for the construction, maintenance, and reproduction of capitalist ideologies (Coakley, 1990; Sage, 1998). Due to the commercialization of sports and the hegemonic work of the mass media, contemporary sports in the U.S. are no longer just private recreational activities, but is a massive commercial industry that “defines and regulates our understanding of what sport is and how it should be played” (Sage, 1998, p.158). The values promoted by sports ideology can be seen from the lengthy description (including statistics) of different players’ characteristics and skills, the use of metaphors like battle and domination in sports news and reports, the emphasis on celebrity athletes and their stories and experiences, and the type of affective photographs that close-up on them. In many instances, the names of some celebrities even become synonymous with the sports they play (e.g., Tiger Woods, Tony Hawk, Michael Schumacher), with the consequential effect of personifying the virtue of these sports in terms of the human characteristics embodied by these celebrities (e.g., adventurous, discipline, resourcefulness).

Such characteristics of idolization and personification form the backbone of sports ideology. They are also quite different from the positivist ideology of reductionism and objectification because of the contrasting set of values. As we saw in the earlier tension between my preference for reductionist-generalizibility and the colorguards’ and cheerleaders’ dispositions for their individual sports’ uniqueness, such ideological contrasts form the basis for how each discourse gives rise to different set of preferences in the framing of phenomena.

The ideological differences between school science and religion are much more polarized and oppositional. This opposition has a long and complicated history beginning from the Age of Enlightenment, to the Butler Act and Scopes Trial in the U.S. in 1925, to the more recent intelligent design movement since the 1980s. Seen from this larger history, the debate between evolution and creationism is not simply about content differences, but is really a political struggle over the legitimacy of different systems of beliefs (atheism vs. theism, liberalism vs. conservatism) and the impact of these beliefs on society. What is at stake in this struggle by different social groups of people is the influence and control of particular public policies, such as school prayer, abortion, immigration, religious pluralism, and the separation of church and state.

At the same time, different ideologies can also mutually reinforce and incorporate one another, thus forming ideological alliances. Ideological alliances can also pose challenges in education. The best example is the ideology of patriarchy commonly found in both physics and sports discourses. In sports, masculine hegemony is predominant in the U.S. This is clearly seen from the type and extent of media coverage on several male-dominated sports (e.g., football, baseball, ice hockey), and the prestige and privilege given to these sports in high schools and colleges. The images of masculinity (e.g., aggression, violent, competitiveness, physicality) promoted through these popular sports greatly legitimize male superiority and reproduce gender stratification and inequalities in sports (Sage, 1998). Although the introduction of Title IX has significantly improved female access and participation in high school and college sports since the 1970s, popular sports remain strongly in favor of male achievement and participation. A recent federal court decision (July 21, 2010) in ruling out competitive cheerleading as an official sport for the Title IX is an example of the negative perception of cheerleading, which originated as and still is a female-dominated sport. This unequal treatment and attention to gender-divided sports is something that the female students in cheerleading and colorguard were very conscious of. This was seen in Melanie's opening statement in her text assignment essay: "There will *always be the big debate of whether or not cheerleading is a sport*, but there is no argument that physics is a huge part in cheerleading".

Masculine hegemony can also be seen in physics, both in the values espoused by the field and the participatory structure within the professional physics community (Keller, 1987; Traweek, 1988). In education, this has given rise to an unequal gender enrollment in high school and college physics and engineering, and is a major issue facing STEM educators. As such, there is an increasing awareness of gender inequality in physics education. It is reasonable to say that today's physics textbooks have become more sensitive to gender stereotypes, and have thus incorporated an equal proportion of women images and word problems using a female character.

However, despite this increasing awareness of gender biases, problems still arise when school physics tries to incorporate sports examples into its own discourse, thereby also unknowingly importing the patriarchy ideology inherent in sports. This was precisely what ensued in the episode where Lucy thought that the pairing of the cheerleaders and colorguards was a form of gender marginalization because their sports were not comparable to "the men sports with a ball in it." Although such marginalization was not intentional on the part of the teachers, Lucy's allegation was not groundless when I look at the examples of the different sports given in their textbook. In the unit on mechanics from chapter 2 to 11, while the number of male to female images is a well-balanced 28 to 24 (supporting my earlier claim that the textbook is sensitive *in general* to gender equality), the number of word problems framed in terms of the various sports is dismally distributed along gender-dominated sports, as shown in Table 7. While male-dominated sports are repeatedly highlighted, there is not a single mention of colorguard and cheerleading throughout the textbook.

Table 7. *Distribution of Problems Framed in Various Sports from Chapter 2 to 11*

Category	**Sport**	**Frequency**
Male-dominated Sports	Baseball	14
	American Football	9
	Ice Hockey	9
	Basketball	6
Mixed Gender	Tennis	7
	Skiing	5
	Soccer	4
Female-dominated Sports	Gymnastics	2
	Cheerleading	0
	Colorguard	0

This discrepancy is particularly striking considering that firstly, most physics problems can be transformed into colorguard or cheerleading related questions, and secondly, there is a substantial number of female students involved in these sports in most American high schools. This was perhaps why Lucy felt that the curriculum had not paid due attention to her sport, even while Brad and I had encouraged her to bring a colorguard text to connect with physics. This illustrates a major problem when the discourse of school physics seeks to incorporate elements from other discourses in order to connect with the students' out-of-school interests.

Summary: Problems in Bridging Discourses

Despite the apparent content similarity between school physics and various out-of-school discourses, this chapter shows that connecting students' prior interests and experiences to the learning of physics involves more than just gaining content knowledge. Instead, it involves a particular way of framing and interpreting natural events according to the semiotic-technological systems available in a discourse. In particular, these systems include: (a) semantic that labels and categorizes our experiences and perception of events, (b) spatial-temporal that shapes our indexing and quantification of our experiences with space and time, (c) visual that influences our "view" of events and reality, and (d) intertextual that brings together our history of text-experiences into juxtaposition with our current interpretation.

Through two textual analyses where I contrasted the different systems in framing common natural events involving movement and the human body, I showed that the phenomena construed in each discourse were actually different. For movement, sports and automobile discourses foreground the human and personal aspects of generating, harnessing, appreciating, and evaluating the movement of athletes and cars, while school physics discourse stresses the impersonal, objectified, and universal forms of motion. For the human body, creationist discourse constructs a phenomenon that directly and personally implicates the reader and his/her relationship with a divine being, while school physics (together with the life sciences as an intertextual system) frames a phenomenon of material interactions among inanimate lexical concepts such as neurons and charges.

Left unchecked, these contrasts can pose problems for student learning. This is not so much in their conceptual understanding (presentational meaning), but more in their stances and attitudes (orientational meaning) toward school science, and inevitably science itself. This is because students' immersion in one discourse not only influences their preferred ways of looking at an event, but also their positive or negative stances toward other ways of looking at the same event from another discourse. Such positive or negative stances toward other discourses are also partly the result of ideological alliances or tensions between different social groups and their underlying interests and values. Thus, when two discourses are juxtaposed in a third space (or any other pedagogy that connects youths' interests to school science), the underlying ideological conflicts among the discourses can lead to the isolation, rejection, and marginalization of many youths toward science. This was particularly the case for female students participating in less privileged sports and religious students who stand by their creationist beliefs.

This chapter thus supports the first part of my "hybridizing understandings" thesis that adolescents are exposed to various ways of understanding and interacting with the natural world in juxtaposition with the ideological dominant view of school science. As multiple discourses (as systems of cultural knowledge of the natural world) are brought into the classroom conversation, the juxtaposition poses a challenging question for educators to address: how can students navigate successfully or unsuccessfully around these multiple discourses? Through my analysis, I found that the key to this question centers around the notion of hybridization, and this is where I turn to in the next chapter.

Chapter 6

Hybridizing Multiple Discourses: The Process of Science Meaning Making through Hybridization

In the last two chapters, I examined the students' funds of knowledge and discourses relevant to their learning of mechanics and electricity. In chapter 4, I illuminated how their out-of-school literacy practices were connected to a network trajectory involving their (a) lifeworld experiences, (b) social affiliations with family, peers, and adults, and (c) use of popular media and cultural artifacts. In chapter 5, I then analyzed the kind of discourses that collectively shaped and are shaped by the networks of text-experiences the students were involved in. In particular, I showed how the discourses of sports, automobile, and creationism contrast with school physics discourse because of their semantic, spatial-temporal, visual, intertextual, and ideological differences. Through these differences, the phenomena construed from a common natural event were different across discourses. Such contrasts created both conceptual and affective challenges for students in learning the discourse of school physics.

In this chapter, I turn to the crucial question of how one could navigate around these multiple discourses, and in the process, how hybridization or the mixing of different interactions with the natural world could take place. In particular, I discuss four characteristics of hybridization manifested in my data. With these four characteristics, I show how some students, given the contrasting funds of knowledge and discourses, managed to make sense of canonical physics concepts and fulfill a requirement of Text-Synergy to explain “like a physicist.”

The Process of Hybridization

Bakhtin Revisited

The theoretical and analytical basis in this chapter build on Bakhtin’s view of hybridization (see chapter 2) as “a mixture of two social languages within the limits of a single utterance between two different linguistic consciousnesses” (1981, p. 358). As I have argued in chapter 3, hybridization cannot be understood by simply looking at “discourses” or “third space” in its abstract sense. Instead, there is a need for a fine grained micro-genetic analysis to dig into the specific utterances and turn-by-turn meanings that people make during their encounter with “different linguistic consciousnesses.” This is the basis for the micro-genetic developmental approach taken in this chapter.

Another insight from Bakhtin (1986, p.69) is the notion of dialogic responsivity whereby “any utterance is a link in a very complexly organized chain of other utterances” that simultaneously responds to preceding utterances and anticipates future responses from an intended audience. Bakhtin called this intended audience the *dialogic other*. Dialogic responsivity is not limited to spoken dialogue between two speakers, but also encompasses other modes of communication between people or even an individual’s self-dialogue (c.f., Vygotsky's inner speech, 1986). Because of this dialogism, no utterance is completely unique and ideologically-neutral as people borrow and adapt others’ utterances and voices in order to construct their own. This gives rise to the notion of *heteroglossia*, or the existence of diverse discourses within a text or speech conversation. These notions from Bakhtin will be further illustrated in this chapter's analysis.

Hybridization as Means for Discourse Navigation

The main assertion in this chapter is that hybridization provided the means for some students to navigate around multiple discourses in a third space. There are four major characteristics of hybridization. The first characteristic is the awareness of heteroglossic differences in the way people use language and representations even when they are talking about similar natural events. The second characteristic of hybridization involves a momentary shift in identification by putting oneself in someone else's (i.e., dialogic other) position during a conversation, thus attempting to understand the conversation from the other's point of view. The third characteristic involves a juxtaposition of the dialogic other's voices in one's utterances as a way of synthesizing multiple perspectives and constructing knowledge collaboratively. Finally, the fourth characteristic involves a strategic and temporary suppression of one's preferred voices in order to fulfil certain short-term goals.

To illustrate these four characteristics of hybridization, I present a micro-genetic analysis of a conversation among two students (Lucy and Evelyn) and the teachers (Brad and myself) that I identified as having significant hybridization. This 30-minute conversation revolved around the students' attempt to apply physics principles in colorguard in order to complete their "text assignment" (see chapter 3 under curricular design). In particular, I show three segments of the conversation to illustrate the first three characteristics: (i) awareness of heteroglossia, (ii) shift in identification, and (iii) juxtaposing multiple voices, within a chronological sequence. At the same time, the micro-genetic analysis also shows, to some extent, the parallel development of Lucy's and Evelyn's conceptual understanding of mechanics. This is then followed by an analysis of Lucy's and Evelyn's essays and post-cycle interviews to firstly, further support my claims about the first three characteristics of hybridization and their corresponding conceptual development, and secondly, illustrate the fourth characteristic of suppressing one's preferences.

There are many reasons why this particular conversation was selected among other examples. First, this conversation, which was based on a mentoring interview setting (see data sources in chapter 3), provides the most comprehensive data in terms of extensive documentation of the moment-by-moment interaction involved in connecting the students' experiences with physics. Besides this extensiveness, another reason is that some aspects of the students' knowledge construction could be traced during the moment-by-moment interaction. Thus, this analysis is also an examination of Lucy's and Evelyn's learning trajectories during the first cycle of mechanics.

Furthermore, among the various mentoring interviews, I deliberately chose Lucy and Evelyn because of their gender and low test scores, which were factors that negatively shaped their interest and self-efficacy in physics. The attention to how female students saw the connections with physics ties in well with the previous chapter that showed the gender biases against them, as well as the next chapter where I will show an improvement in female students' attitudinal survey scores. As for their self-efficacy, given their relatively low test scores (to be elaborated later), their knowledge construction observed during the conversation and demonstrated in their essays provide an interesting contrast and counter-example to their relatively poor test performance.

Because of the situated nature of their discussion and essays, the purpose of the analysis is not to make universally generalizable claims for the specific processes of hybridizations and their relationship with knowledge construction. Rather, it is to gain a deeper understanding into an important process that is relatively under-studied and under-theorized. Nevertheless, I will also compare the findings from Lucy and Evelyn with the hybridization from Naomi at the end of this chapter in order to further support and extend my findings.

From here on, I will address myself in the third-person to distinguish my role as a co-teacher and participant-observer, and reserve the first-person for my role as an analyst and writer.

Characteristics of Hybridization

Contextual Information

Text assignment. I will first elaborate the requirement of the text assignment, which was the focus of the analyzed conversation. The requirement of the assignment was first discussed among the teachers (Brad and Kenneth) in early February after choice texts from the first cycle were collected and examined. Based on an initial assessment, the teachers brainstormed several criteria for the assignment. One of the criteria was that the students should be able to use what they "have learned in the physics classroom and applied it" (Brad, Feb 2) to understand and critique their choice texts. Besides being able to apply the physics knowledge gained in class, the teachers also felt that it was important for them to be "like a physicist" in using appropriate scientific terms and representations, instead of the non-scientific language and representations found in their texts. After several drafts by Kenneth, this criterion eventually developed into the following instruction in the text assignment (see appendix F for the complete instruction):

> A step-by-step **scientific explanation** of the phenomenon using the principles of physics. Your explanation should use the appropriate physics vocabularies and representations (e.g., diagrams, graphs) you have learned from the class. Whenever possible, apply relevant formulae and do some calculations. Use reasonable estimates for the numerical values based on your text and personal experience.(**bold** in original)

Because of the diversity of the students' choice texts, the teachers also developed a scoring rubric to standardize the expectation and grading for this assignment. Some aspects of this rubric reinforced the teachers' preference for an appropriate usage of "precise and accurate" scientific terms and "relevant and accurate representations" according to school physics discourse. Because the rubric spelled out to the students their expected grade for different levels of performance, it functioned as a means by which the teachers' preference for a certain way of explanation was institutionalized in the classroom. In addition, Kenneth also wrote an exemplar based on a student's interest and choice text on skateboarding so as to model the teachers' expectations. Overall, this rubric and exemplar had a considerable impact on the students as they were quite academically competitive in general.

The text assignment (including the rubric and exemplar) was introduced to the students on March 23, and Lucy and Evelyn were both present on that day. During class, Brad took about 30 minutes to go through the requirement with the students, while frequently stressing the importance of "explaining what is happening and why *like a* *physicist would*." This referencing to the identification of a physicist was not the first time it occurred, but was something that the students had already heard from Brad many times. The following lists several physicist identifications made by Brad in terms of the way physicists talk, write, read, draw, and think:

- "Good physicists do that, they take that extra step [to make a sketch]" (Feb 12).
- "You become good in vocabulary by using them correctly and consistently, so when you come in here, you talk like a physicist, you talk and communicate like a physicist" (Feb 12).
- "We are advanced physicists, we like to be technical correct. So we use positive and negative acceleration, not deceleration" (Feb 19).
- "Scientists don't like flowery writing. We like straight to the point, clear and concise. We tend to like that and we tend to write that way, and we tend to only read things that way as well" (Mar 11).

Such uses of identifications are quite common among science teachers. As Moje (1995) points out, they are used as strategies to establish and draw students into a relationship with teachers as fellow scientists, thus encouraging them to communicate like scientists. Through this assignment, the use of scientific language took on greater significance as credits were given for students meeting this requirement.

The event. The conversation with Lucy and Evelyn took place on April 21. It was first suggested by Brad, who thought that it would be interesting to "interview" some students as they worked on their assignment. These interviews became what I have called "mentoring interviews" in chapter 3. Lucy and Evelyn were the first few to be selected because they coincidentally[9] had the same choice text on colorguard. Thus, from their common set of text and experiences, the teachers could compare two different students

[9] This coincidence occurred because Lucy and Evelyn used the same keywords and search engine to look for their texts. In other words, this coincidence could be explained by their shared network and funds of knowledge. It must be noted that they did not intentionally look for the same text.

working on a similar project. Following Brad's suggestion, Kenneth approached both students to have a conversation with them, which they readily agreed. Kenneth also related to them that the purposes of the session were two-fold: the first was an instructive one to help them manage their assignment and the second was for his research to video-record and understand how they managed it.

There were several key prior events that had bearing on the conversation of April 21. One of them was Kenneth's first interview with Lucy two months ago[10]. During this interview, Kenneth and Lucy talked about her choice text, which was a student-made video about the "Physics of Colorguard" (the video's title) posted on YouTube. In a particular exchange, Kenneth played a part of the video that exhibited some inaccuracies in the use of physics terminologies and asked Lucy if she could identify it. As will be warranted later, that exchange during the interview made Lucy particularly sensitive toward the use of appropriate language and had a significant impact on her sensitivity toward the dialogic other, more so than Evelyn, during her later interaction with Kenneth on April 21.

Another prior event was the term examination on mechanics one week earlier. Both Lucy and Evelyn received the same grade of 67.1%, which placed them at the bottom 10 percentile of the class. These grades had a negative impact on their self-efficacy in mechanics, which consequently affected the conversation on April 21. For instance, whenever Kenneth tried to connect the discussion to some prior concepts or chapters in the textbook, they would remark about their inabilities to recall or understand them, like "I don't remember anything, that's why I failed the final" (Lucy in turn 302),

[10] An interview with Evelyn was also planned prior to the introduction of the assignment. But due to scheduling conflicts, this did not materialize.

and “No, I didn't get last chapter” (Evelyn in turn 142). However, as I will show in the analysis, despite their poor test performances, they demonstrated a sophisticated knowledge of free-fall, showed great ability in problem-solving, and were able to understand the underlying physics concept quickly when Kenneth explained in the context of colorguard. Thus, these must be taken into consideration as their knowledge construction is evaluated.

Initial breakdown: Heteroglossic System of Preferences

The following micro-genetic analysis is divided into several sequential segments. (See Appendix G for a full transcript of the conversation.) I will begin with the first segment, which shows an early tension due to the heteroglossic discourses among the teachers and students, particularly the different systems of preferences in using verbal-gestural mode in colorguard as opposed to the abstract-visual mode in physics. This not only further supports the claim of conflicting discourses I have made in the previous chapter, but also sets the context for understanding the subsequent hybridization and knowledge construction efforts in bridging the discourses.

The conversation with Lucy and Evelyn began with Kenneth asking them if they had talked to each other about their assignment. Lucy responded that she had discussed it with Evelyn to make sure their work did not overlap as both of them had the same video. They had decided that Lucy would work on tossing a rifle, while Evelyn on a flag. Each of them then went on to explain how tossing a rifle and a flag were different. In the following excerpt, it was evident that Kenneth could not fully comprehend their explanations (orchestrated using a verbal-gestural mode) despite the students’ repeated attempts to do so. He then took steps to ask them explain in a different way by using a visual system.

Time	**Turn**	**Speaker: Utterance & Non-verbal Actions**	
01:37.3	19	K	So the only difference is because one is a rifle and one is a flag?
	20	E	Yah, [like the]
01:40.6	21	L	[Yah but] like the way they are weighted and the way they tossed are different. Like with the flag.. (*L & E looked at each other for 2 seconds*) Um.. you're not trying to. sorry, like **the best way to explain** it is on a rifle. The center of the rifle goes straight up and straight back down (RH traced a line forward and backward on the table)…
01:55.6	26	E	For flag like. the center of the flag like it starts up here (*both hands imitated holding flag position; see Figure 17*) and it's gonna basically go straight up and down (*LH traced an imaginary line upwards and downwards*) But. it ends up kinda curving (*RH tracing an imaginary arch*) because it's like bigger. and like.. it does not. I don't know. it doesn't like rotate it's like click (*RH doing a rotation motion*) ….
02:53.4	36	K	Okay, you know what will help me a lot, and. and I think will help you as well is to. **draw what you just said**. And so I'm going to give you some pieces of paper.
	37	L	Right
02:58.5	38	K	I want you to draw. whether is it a rifle or flag and. **draw some arrows** and. talk to each other, and I want to see how it goes. [Okay?]
	39	L	[Right]
	40	E	[Okay]
03:06.3	41	B	**Perfect**. **You read my mind** (*laughing*)
	42	K	(*Laughing*) Well. you see. we always think alike.

K – Kenneth; E – Evelyn; L – Lucy; B – Brad; LH – Left Hand; RH – Right Hand
(See p. xvi for the rest of transcription notations.)

In turn 19, the phrase “only difference” in Kenneth’s questioning shows that he did not quite appreciate how the two tosses were different apart from the equipment used. This sounds reminiscent of his reductionist comment to Lucy, Evelyn, Naomi, and Melanie just two days ago that colorguard and cheerleading tosses “are quite the same in terms of the physics" (see chapter 5). Kenneth's question immediately led to Evelyn's and Lucy's objections[11] that there was more to it in "the way they are weighted and the way they tossed" (21), and subsequently led to Lucy's third attempt (see full transcript) to explain the differences. From Lucy's utterance in "the best way to explain it", it was apparent that she had thought of explaining it in a way that would be comprehensible to both Kenneth and Brad who were listening.

Despite Lucy's and Evelyn's repeated attempts to rephrase their explanations, they were still operating within a colorguard's semiotic-technological system of verbal-gestural modes. The use of gestures was prominent in turn 21 and 26; for example, Lucy's finger tracing a line forward and backward in synchronization with her utterance of "up" and "down" (21), and Evelyn's right hand tracing an imaginary arch as she uttered "kinda curving" (26). As explained in chapter 5, this reliance on gestural actions is an intricate feature of colorguard discourse. This occurred as these gestures mediated their textualizations of their colorguard bodily actions enacted beyond the classroom into the words uttered within the classroom (see text-experience reciprocity in chapter 4). An exemplar can be seen in turn 26 when Evelyn's hands enacted a posture of holding an imaginary flag as she said the flag "starts up here" (see Figure 17). Through such uses of words and gesture, this was how the flag and its motion were discursively constructed. In a sense, this was like an actual performance where Lucy and Evelyn enacted through gesturing and verbalizing their thoughts for the teachers to understand what they did in colorguard, particularly the subtle differences between tossing a rifle and flag.

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[11] Although Evelyn and Lucy first responded with a "yah", this was due to a brief agreement (perhaps out of politeness; see Pomerantz, 1984) that the equipment does constitute some differences. However, it is clear that their responses were more oppositional than in agreement.

Figure 17. Evelyn (left) enacting a tossing position while Lucy (right) looked on.

Kenneth's difficulty (or perhaps reluctance) in discerning the students' repeated explanations in the tossing subtlety was witnessed in turn 36. This could be explained by the contrasting phenomena framed by two different discourses; with colorguard discourse elaborating bodily movements and actions, while school physics discourse reducing them to objectified motions with abstract properties. After hearing Lucy's and Evelyn's previous explanations using their colorguard language and gestures, Kenneth took a drastic shift in turn 36-38 by introducing into the conversation his system of preference in explaining a natural event – the visual system used in school physics discourse. When Kenneth instructed them to "draw what you just said" (36), he was asking for a specific way of drawing that was similar to a free-body diagram. This was further made clear in (38) in his instruction to "draw some arrows." Brad, who had been listening to the conversation made an interesting remark that showed his "perfect" agreement (41) with Kenneth's suggestion. Although Brad's casual remark of "read my mind" was only metaphorical, it pointed out the common discourse that he and Kenneth were familiar with, and more importantly, showed preference for. In other words, it was their shared membership within the school physics discourse community that made it possible for them to “read” each other’s mind (41) and to “always think alike” (42), including their preference for using a visual diagram.

In general, high school students do not readily use drawing as they describe their out-of-school activities or even when they are solving a physics problem. In my interviews, none of the students ever initiated making a sketch unless I prompted them to do so. During physics class, students were also reluctant to draw a diagram in their problem solving even though they were taught and encouraged to do so. Thus, Brad had to repeatedly remind and encourage them to make sketching a habit, as was seen from one of his appeals to physicist identification: “Good physicists do that, they take that extra step [to make a sketch].” Based on my findings in chapter 5, this lack of conviction in using visual diagrams is best explained by the difference in habitual intertextuality (Ivanic, 2004); that is, it is not typical in students’ out-of-school discourses to juxtapose a schematic diagram with the current text they are reading or producing. Thus, when Kenneth introduced the visual component in this segment, it was not simply telling Lucy and Evelyn to draw what was “already in their mind”, but it was an overt instruction for them to incorporate a contrasting visual and intertextual system from another discourse.

This also explains why Lucy and Evelyn did not attempt to make a sketch and instead relied heavily on their system of preference of using oral and gestural modes in their repeated explanations. By contrast, it explains why Brad immediately responded with “you read my mind” (41) to Kenneth’s suggestion. Based on the students’ quiet compliance (e.g., “right”, “okay”), I infer that they were initially not keen to take up Kenneth’s suggestion. Maybe they felt frustrated because the teachers could not understand their earlier repeated explanations, or because they had to explain in terms of the teachers' system of preferences (e.g., using a diagram). Nevertheless, because of the intertextual addition of this visual element, what ensued next was a critical moment of hybridization manifested during the conversation.

Awareness of Heteorglossia and Dialogic Other

Shortly after the last segment, Naomi walked into the classroom to get assistance for her assignment (on cheerleading). She and Brad then sat down and began a conversation at another table. After adjusting the camera composition to include Lucy's and Evelyn's drawings, Kenneth then walked over to Naomi and Brad and audio-recorded their conversation. Thus, for the next 3 minutes when this and the next segment took place, Lucy and Evelyn were on their own as they made their sketches and commented on their drawings, while the video camera continued recording. Lucy's cognizance of the video recording was largely what prompted the following segment to ensue:

Time	**Turn**	**Speaker: Utterance & Non-verbal Actions**	
04:46.3	57	E	(*E looked at her initial sketch and mumbled to herself*) Okay. So.. this is my gas.
	58	L	(*Looked over at E's sketch and laughed*) Your gas?
04:48.4	59	E	Well, that's how I [start (*inaudible*) right?]
04:49.2	60	L	[Right.] So essentially.. say which hand (*pointed her pen at E's sketch*) is the gas and which hand (*looked at and pointed her pen toward camera*) is the..
04:53.1	61	E	Okay, well. my push down (*pushed her LH downwards*) is the gas, and this (*raised up her RH*) is my steering, so.
04:58.0	62	L	Your height.
04:59.0	63	E	My.. (*laughed*) okay.

05:00.1	64	L	Oh no, I'm just. (*pointed her pen toward camera*) I'm like **I'm explaining it to the**. (*looked at the camera*)
05:02.1	65	E	Oh (*looked at the camera*)
05:02.3	66	L	**the video**.
	67	E L	(*E drew an arrow up on left side and arrow down on right side of her figure; see Figure 18, as L watched*.)
05:07.8	68	E	Okay, this is.. my HEIGHT.. This is my. rotation. (*wrote height and rotation next to her sketch; see Figure 18*)

A critical moment took place when Lucy demonstrated her keen awareness of the Bakhtinian dialogic other, even when this "other" was an inanimate camera directing at them. When Evelyn muttered to herself "this is my gas" (57), Lucy interrupted to mediate between Evelyn's talk and the video recording. This was clearly seen in (60) when she looked and pointed at the camera as she directed Evelyn to "say which hand is the gas." At that moment, Evelyn did not see Lucy's gesture toward the camera, but she nevertheless casually replied "my push down is the gas, and this is my steering." (Note that she did not verbally state left or right hand, but used her gestures instead.) After she said that, Lucy corrected her again to say "height" (62) instead of "steering." At this point (63), Evelyn found this correction rather amusing, thus indicating that this was unusual among their everyday talk. Lucy then explained to her that she was just "explaining it to the video" (64, 66). Only then was Evelyn reminded that they were being video-recorded for Kenneth's research, and so they needed to translate for someone who was an outsider to their colorguard discourse. Five seconds later in (68), Evelyn stressed "HEIGHT" clearly as she wrote that down in her sketch next to the right hand of her straw man (see Figure 18), and self-corrected her own earlier use of the term "gas" and replaced it with the more appropriate "rotation." These self-corrections show that Evelyn's subsequent utterances and actions were made in due consideration of the dialogic other.

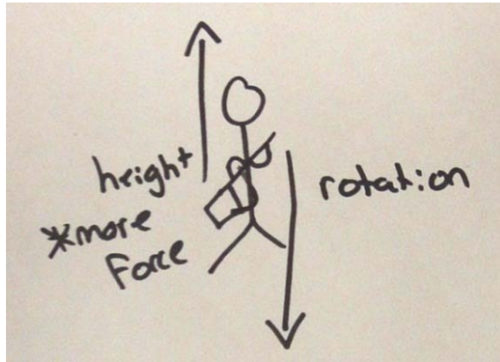

Figure 18. Evelyn’s sketch of her bodily actions taken during a flag toss.

This exchange shows the first characteristic of hybridization: the awareness of heteroglossic differences in the way people use language and representations even when they are talking about a similar natural event. In this case, the event was the toss of a flag, and there were multiple terms used to describe various aspects of the toss. Lucy was aware that certain terms might be incomprehensible to Kenneth, and thus took the initiative to correct Evelyn’s choice of technical words (e.g., steering) to something he would understand. Her choice of the word “height” was appropriate not only because it is a simple word, but also because it is a word commonly used in physics in dealing with vertical motion and acceleration. Although Evelyn was initially oblivious to the camera, her subsequent responses after being reminded by Lucy also showed her awareness of the heteroglossic differences, as could be seen from her own translation from “gas” to “rotation.” Besides this segment, there were also many other instances of Lucy and Evelyn showing their awareness of heteroglossic differences, which I will point out as the analysis unfolds.

Shifts in Identification Toward the Dialogic Other

In this segment, which followed immediately after the last one, Lucy continued to play her role as the facilitator between Evelyn and the camera as the dialogic other. (Kenneth remained absent in this segment). Thus, there was further development in their awareness and translation for the dialogic other (first characteristic). This subsequently led to the manifestation of the second characteristic of hybridization: a momentary shift in identification on Lucy's and later Evelyn's part to talk and think like the way a science teacher would.

Time	**Turn**	**Speaker: Utterance & Non-verbal Actions**	
05:17.7	69	L	Right, so which hand uses more.. (*shook her head*) which hand. **has more force**.. if you are throwing a double?
05:23.7	70	E	(*Uttered a long sigh*) The height.
05:25.8	71	L	Yah. (*smiled at E*)
	72	E	Yah.
05:26.5	73	L	Yah.
	74	E	Yah. (*laughing*)
05:28.0	75	L	Yah.
05:29.5	76	E	(*Uttering to herself as she looked at her sketch*) This hand **has.. more force..** (*wrote more force on right side of diagram*) (*whispering*) **I don't know why..**
			(Looking at her sketch for 8 seconds)
05:37.4	77	E	Cos if I. if it doesn't, then it's just gonna.. be too low
05:40.2	78	L	Or.. Going to the ground if you use too much of the.. left hand than the other [hand]
05:44.0	79	E	[Right]

Following Evelyn's actions in the last segment, Lucy, who had been watching her sketching, further asked Evelyn to state "which hand has more force" (69). After

Evelyn's answer – "the height" was given in (70), Lucy's followed up response of "yah" (71) shows that the answer to her earlier question in this exchange structure (69-71) was something that was already obvious to both of them; it was part of their tacit experiential knowledge. In other words, Lucy was enacting an I-R-E (Initiate-Response-Evaluation) sequence and making their tacit knowledge explicit for the camera. Evelyn's sigh in turn 70 and their back-and-forth strings of "yah" and smiles from 71 to 75 further show their mutual awareness that they were simply enacting this exchange for the dialogic other.

Lucy's self-repair (Schegloff, Jefferson, & Sacks, 1977) from "which hand uses more" to "which hand has more force" in turn 69 is particularly illustrative of her deliberate use of language to talk about force appropriately (her sensitivity toward the choice of words will be further warranted later). This sensitivity in using the correct physics word, coupled with the I-R-E sequence that she initiated, showed her momentary identification with the role of a teacher-facilitator in getting Evelyn to explain what she was drawing in a way that could be recognized by someone outside their colorguard discourse.

The I-R-E exchange, initiated by Lucy, later prompted Evelyn to say in (76) and write down "more force" next to the sketched right hand (see Figure 18). She then pondered why that was so and subsequently postulated a reason. After 8 seconds of looking at her drawing, she started to answer her own question by stating a possible outcome that it would "be too low" if less force was exerted (77). This was then followed by Lucy suggesting another probable outcome (78). Throughout these two exchanges of I-R-E sequences (from 69 to 75) and self-question-and-answer (from 76 to 78), it was as though they were anticipating what Kenneth would say to them if he were present. In

Bakhtin's term, they had appropriated the expectation of the dialogic other in their momentary utterances.

Evelyn's self-questioning on the consequence of "force" followed by their postulated explanations demonstrated a way of thinking and questioning that departed from their usual colorguard talk. This arose because the reflection of someone else's way of talking and questioning about force (i.e., Kenneth as the dialogic other) prompted them to ask questions that they had not and probably would not conceive. This was an instance of a shift in identification where Lucy and Evelyn appropriated the dialogic other's expectation and reasoning process. In doing so, they had mixed their tacit experiential knowledge of colorguard toss with the dialogic other's use of language and way of thinking. Consequently, this generated new interpretations that became instrumental for their subsequent knowledge construction in the next segment.

Juxtaposing Voices in Knowledge Synthesis

This segment illustrates the third characteristic of hybridization: the juxtaposition of the dialogic other's voices in knowledge synthesis. Before showing the segment, I want to point out several instances of voice juxtaposition in the previous segments. One instance was the mixing of verbal utterances, images, and gestures across discourses, which started when Kenneth first asked the students to "draw what [they] had said" (36) in the first segment. Thus, as Lucy and Evelyn drew their diagrams, what ensued was a textualization of their embodied gestural actions from prior experiences to a symbolic system of a different discourse (i.e., free-body diagram). As such, the subsequent drawings made by Lucy and Evelyn (see Figure 18), though derived from their textualized experiences, were populated with the "voices" of school physics discourse in terms of the features of free-body diagrams. Furthermore, the previous segment also showed the juxtaposition of the term "force" in their textualized utterances. As was shown, it was through such hybridized textualization and juxtaposition that Lucy's and Evelyn's attempts to bridge toward school physics from turn 69 to 79 were made possible as they reflected on the consequences of force in the context of their tossing experiences.

In this segment, the mixing of multiple voices, in terms of the words, images, and gestures across discourses, was again very prominent. However, what this segment will illustrate is a more intense collaborative knowledge construction and a certain degree of synthesis of multiple perspectives among Lucy, Evelyn, and Kenneth.

Time	**Turn**	**Speaker: Utterance & Non-verbal Actions**	
06:34.9	105	L	(*Looked at her sketch as she spoke to Kenneth*) And like. in rifle.. before you toss, like there is a prep. So like instead of tossing from. flag up and down, you. like. (*looked at K*) **gain your momentum** by like. basically.. like. prepping. (*LH raised up while RH went down*) [like to get ready]
06:47.8	106	E	[It's like a. it's] called the dip. Like. you get start up at an angle, (*both hands enacted position*) so you **get more..** (*RH raised up; 2 sec pause*)
06:51.4	107	L	(*Looked at her sketch*) So like the.. the speed you get going down and coming back up. gives you.. the.. (*looked at E*) **momentum? The mo.. hmm.. no, I don't think it's momentum. It gives you the.. energy** you need. [to.]
	108	E	[Yah.]
	109	L	be able to get it around.
07:03.5	110	K	Okay.
07:04.5	111	E	And like.. but on flag, you already start at your angle. (*both hands held flag*) And. you like **use the time** like to take you back up into the air (*LH raised up*) to like **build momentum or energy or whatever**.
07:14.4	112	K	So you saying that uh. when you toss your rifle, you have. there's **more time**. for you. from that position to when you release it?
	113	E	(*Nodded her head*)

07:21.0	114	L	Alright, you start here. (*both hands held imaginary rifle horizontal*). You go down (*enacted dip position*). And then you release (*both hands flipped*).
07:24.5	115	K	Yah, exactly. So. so there's **more time** you're. you are [holding]
	116	E	[Yah..]
	117	K	the [rifle right?]
	118	L	[Yah.]
07:27.4	119	E	(*Both hands held flag*) [It like **increases] the time**. to like.. (*LH lowered and RH raised up)* **build up the momentum and energy before you release** (*RH raised up*) so like it goes higher like and spins..

After the last segment, Kenneth returned to the table and asked the students what their diagrams represented. From their responses, the effect of acknowledging and translating for the dialogic other (who was now physically present) continued in this segment. One instance was seen in (106) when this time it was Evelyn who recognized Lucy's earlier use of the word "prepping" (105) might be foreign to Kenneth, and so offered the context of the word and its proper term in colorguard **–** "the dip" (106).

A key aspect of collaborative knowledge construction in this segment arose from the use of the technical word "momentum", which was first uttered by Lucy in (105) and subsequently self-corrected in (107), and later appropriated by Evelyn in (111) and (119). In turn 107, Lucy's explicit self-correction from "momentum" to "energy" was another piece of evidence of my earlier claim that she was sensitive in using appropriate physics terms (previous evidence was on "force"). As many studies from Physics Educational Research have shown (e.g., Itza-Ortiz, Rebello, & Zollman, 2003; Touger, 2000), students tend to use words like "force", "momentum", and "energy" in their everyday contexts when talking about motion. Against this finding, Lucy's conscious use of the appropriate term was particularly striking, even when both usages of "momentum" and "energy" were technically correct in the context of her explanation. Thus, her doubt as to whether momentum or energy was more accurate further lends support to her sensitivity toward using appropriate language.

It is revealing to see how Evelyn, who had been co-constructing the explanations with Lucy, appropriated these various technical terms. In turn 106, when she was initially trying to explain why "the dip" starting from an angle is important before the toss, she could not find the correct word to complete her sentence in "so you get more… ." In the next turn (107), Lucy then completed Evelyn's explanation by first suggesting "momentum", but later corrected that to "energy." Following Lucy's self-correction, Evelyn's subsequent explanation in (111) showed that she had not made up her mind whether it should be "momentum" or "energy", and so she completed her utterance by giving both: "build momentum or energy or *whatever*."[12]

Although Evelyn was unsure which vocabulary was more appropriate, the adoption of these technical terms first introduced by Lucy was necessary in constructing her explanation first attempted in (106), and later completed in (111). Subsequently, her later explanation became instrumental for the remaining segment from (112) onwards, which I identified as a critical moment of physics knowledge construction. In her explanation in (111), Evelyn first introduced the idea of using "the time… to build momentum or energy." This was immediately taken up and revoiced by Kenneth to "*more* time" from the dip to the point of release (112) and "*more* time [they] are holding the rifle" (115). Such revoicing (O'Connor & Michaels, 1993) is a common pedagogical

[12] An alternative interpretation could be that Evelyn's hesitation in (106) to take up the word "momentum", which was first uttered by Lucy in (105), casted doubt on Lucy that that usage was incorrect. This led Lucy to correct herself in (107), and this is also supported by the possibility that when Lucy said "energy", Evelyn immediately uttered "yah" in (108). Thus, this interpretation would suggest that it was Evelyn, and not Lucy, who first thought that "momentum" was not the correct term to use. However, because Evelyn was still uncertain in (111) by using "momentum or energy or whatever", I reject this interpretation in favor of the one I presented in the main text.

strategy used to reformulate a student's response toward more appropriate usage in the guise of a confirmation check, such as "are you saying that?" by Kenneth in (112). The reason for this revoicing was because Kenneth was anticipating and preparing for a suitable moment to introduce the impulse-momentum theorem, which he subsequently did minutes later.

What Kenneth's revoicing did was to include an adverb of degree with the use of the qualifier "more" in "*more time*" (112, 115), thus adding a meaning-by-degree dimension (Lemke, 2003) to it. This thus changed Evelyn's earlier meaning of "time" as a subjective and experiential sense of pacing during a colorguard toss to a degree of variation of "time." After this revoicing, Evelyn appropriated that meaning-by-degree dimension and turned it into a more refined explanation in (119) that "[the dip] *increases the time* to build up momentum and energy before you release so it goes higher."

A key feature in this segment was how both sides collaborated in the knowledge construction process by building on one another's ideas and ways of speaking, and how hybridization was a significant part of it. Figure 19 summarizes how the progression of ideas took place in this sequential chain of events. Starting from Lucy's self-correction from "momentum" to "energy", both terms were adopted by Evelyn, and in that process, she introduced the next idea of an experiential sense of "time." This experiential time was further revoiced by Kenneth, which was in turn re-adopted by Evelyn in her final utterance to combine with the earlier notions of momentum and energy first introduced by Lucy. This back-and-forth correction-adoption-revoicing by the various people was how their ideas could collaboratively accumulate and progress forward.

Lucy	**Evelyn**	**Kenneth**
momentum (I)		
→ energy (C)	→ momentum & energy (A)	
	time (experiential) (I)	→ more time (degree of variation) (R)
	→ time (degree) + momentum & energy (A)	
		→ delta *t* & *mv* (R) (in later exchanges)

(A) = Adoption
(C) = Correction
(I) = Introduction
(R) = Revoice

Figure 19. Collaborative building and progression of ideas in this segment.

In order for their collaborative ideas to build up and carry forward, multiple terminologies and semiotic systems from both discourses had to be used and juxtaposed in almost every extended utterance. The final utterance by Evelyn in (119) is the quintessential exemplar of such hybridized juxtaposition: “It [the dip] like increases the time to like (gesturing) build up the momentum and energy before you release (gesturing) so like it goes higher.” This utterance simultaneously juxtaposed: (a) “dip” and “release” from colorguard with “momentum” and “energy” from physics, (b) Evelyn’s gestures textualized from her prior tossing experiences with her sketch showing a “dip position”, and (c) several ideas built up from preceding utterances and visual sketches (e.g., prepping, more time, from one spatial position to another, accumulating momentum/energy). As shown in Figure 19, this hybridized juxtaposition was a direct result of “populating” the voice of an utterance by the back-and-forth movement of ideas across the various people (and their associated discourses). Such juxtaposition of multiple voices in their utterances is indispensable in synthesizing the students’ prior interests and knowledge with the formal literacy and knowledge demanded in school physics, and illustrates the third characteristic of hybridization: juxtaposing voices for collaborative knowledge synthesis. It also illuminates how collaborative knowledge construction works within a "zone of proximal development" (Vygotsky, 1986) with an experienced adult from a school-based discourse. The comparison of hybridization with Vygotskyian ideas will be further discussed in a later section.

Corroborating evidence from essays and interviews.

Evelyn: better conceptual understanding.

From Evelyn's essay and post-cycle interview, further evidence can be found to support the claim that the hybridization process was instrumental in enabling Evelyn to synthesize knowledge across both discourses. First, there were several instances in Evelyn's essay (see Appendix H) that showed her direct appropriation of several ideas and concepts discussed during the conversation on April 21. One example can be found from the following excerpt:

> Because you (sic) hands are working in opposite direction the right hand has to *have more force* than the left *in order for* the flag to overcome the *downward force* and go in the air.

This explanation was a direct follow up from the previous segment where, as a result of their I-R-E enactment for the dialogic other, she stated and gestured "this hand *has more force*.. [but] I don't know why" in (76). As that segment showed, from a shift in identification by appropriating the dialogic other's way of thinking, Evelyn came up with a reason herself based on what would happen if the right hand "doesn't" have more force (77). In the above excerpt from Evelyn's essay, not only did she appropriate those arguments, she also further refined it using a more scientific language such as the use of a causal conjunction “in order for” and the nominalization of a “downward force.” This is one piece of evidence that Evelyn’s hybridization through the shift in identification had facilitated her to make that explanation.

By Evelyn’s own admission, she also recognized that through the assignment and the conversation with Kenneth and Lucy, several concepts that she had initially “trouble grasping” now “made more sense when [she] put it in with colorguard.” In a particular moment during the conversation as they were discussing the relationship between free-fall acceleration (g = 9.8 m/s^2) and the time and height of a toss, Evelyn even exclaimed that “this would be useful to know when [she] took the test” (296). During the post-cycle interview, I probed her to elaborate why she made that comment:

> Before I took the test, I didn't really understand what is going on… and then like sitting down and thinking like, “oh, if I get a flag going up”, and how you [Kenneth] would try to like. everything kinda makes more sense. with like finding the velocity… It kinda clicks more knowing like, “oh, if I toss a flag, it will this happens and this happens”, I know this happens so this equation makes more sense now, like why they happen like that... After we did this, it was a lot easier to do my text assignment cos I kinda knew what was going on now. And it makes the concepts more clear, like easier.

Based on her elaboration, several elements that led to her better conceptual understanding can be identified. One was the role played by Kenneth in scaffolding the discussion and explaining the concepts and formulae (see discussion on scaffolding later). Another reason was also the contextualization of the equations and concepts in Evelyn’s colorguard tossing experiences. This was seen in her own hybridized utterance above as she juxtaposed two personal narrations in direct speech (e.g., “oh, if I get/toss a flag”) with what she was taught in class. Her statement in “I know this happens so this equation makes more sense now" implied that through her experiential knowledge in the sequential actions of a toss, textualized through a visual sketch (see Figure 18), she was able to understand the equations of free-fall and Newton's second laws. In other words, it was the hybridization process during the conversation that had made "the concepts more clear [and] easier" for her.

Evelyn's self-evaluation of her conceptual understanding was corroborated by several follow-up questions that I asked to confirm what she understood. An example was her new understanding of *g*. In a prior multiple choice test question, she erroneously indicated that the acceleration of a ball tossed vertically upwards is always "in the direction of motion", instead of the correct answer of "directed downwards." During the interview, she confidently stated that the downward direction and magnitude of *g* were the same for both upward and downward motion. She further explained:

> I knew 9.8 was like when the object is falling and I never really felt like that's when it is going up too until we actually did this and now I like oh, that actually makes a lot more sense now.

Lucy: heightened sensitivity toward heteroglossia.

Unlike Evelyn, the impact of the conversation of April 21, particularly its knowledge construction aspect, was harder to trace in Lucy's written explanation (see Appendix I). However, Lucy's interview provided a key explanation to an intriguing question that surfaced in the earlier analysis in several instances: why was Lucy particularly sensitive toward the dialogic other, more so than Evelyn? One answer lies in the first interview she had with Kenneth, thus suggesting that Lucy had undergone a previous hybridization process where she gained a heightened sensitivity toward the appropriate use of terms by the dialogic other. This was best shown by what she said about her concern in using the wrong word during the interview:

> I was a little bit worried about my terms in the explanations… It was like I might have this worded wrong. *I'm just going to re-word this altogether*. So I'm not going to be wrong. Because that was my biggest concern on it. Um.. and I *remembered like when we talked last time*, there is a mistake in the text like, can you find it? I like reviewed that and *make sure I didn't make that mistake. So I like learned from that.* (*italics* added)

When Lucy said "remembered when we talked last time", she was referring to a particular moment during the first interview where Kenneth showed Lucy a slide from her choice text and asked her to interpret what it was saying. This slide, as shown in Figure 20, had the following statement written by its author (a middle school student): "The force the girl exerts will be overcome by the force of gravity, and will come back down in a slight parabola." It is worth noting that this explanation exhibits a common "misconception" called the impetus theory, which holds the existence of an internal force (the impetus) will gradually die away due to gravity (McCloskey, 1983). Lucy's re-interpretation was that the rifle "comes back down because the *energy* [the girl] puts on it will eventually run out." Because she explained in terms of "energy" instead of "force", I asked her to explain the difference between those two words and their usages. I then informed her that there was a mistake in that explanation (without telling her what it was). At that time, before Newton's Laws was formally taught, Lucy could not spot the problem with the slide's explanation. However, what is important is that it had taught her to be mindful of using different terminologies in physics explanation, as she admitted in the above excerpt: "so I like learned from that."

Figure 20. A slide from a colorguard video selected by Lucy and Evelyn.

In the above excerpt, Lucy also explained how she approached her essay in order to fulfill its requirement of writing like a physicist. Her strategy was to "re-word this altogether so [she's] not going to be wrong." Although she could not recall a specific example of her "re-wording" when I probed her during the interview, based on my analysis of her essay, I found that the best example was her total avoidance of the word "momentum" and reference to Newton's second law. In the earlier micro-genetic analysis (turn 107), there was an instance where she was unsure about the usage of this term and its underlying concept, as seen in this utterance:

> So like the.. the speed you get going down and coming back up. gives you.. the.. *momentum? The mo.. hmm.. no, I don't think it's momentum.* It gives you the.. *energy* you need. to. (*italics* added).

Lucy's uncertainty in the use of the momentum as a concept was consistently demonstrated in her essay where she chose to explain in terms of energy instead of momentum or Newton's second law. Thus, in order that she was "not going to be wrong", she had strategically avoided using a technical word she was not familiar with (she recognized momentum had a specialized meaning different from its everyday usage). She did this because she did not want to be penalized or marked down in the assignment.

Given that the grade for her explanation was 95% (65-95 percentile), this strategy seemed to work very well for her.

Strategic Suppression of Preferences for Short-term Goals

Lucy's strategy to avoid being wrong in her choice of words highlights an important aspect of the student's active resourcefulness in managing the demands of this academic assignment, and so illustrates the fourth characteristic of hybridization. This involves a strategic and temporary suppression of one's preferred voices in order to fulfil certain short-term goals, most notably obtaining a good grade. A case in point can be seen in how Lucy and Evelyn, in the course of fulfilling their assignments, had to adopt a reductionist stance to simplify their elaborated and colorful sport into abstract terminologies, symbols, dots, arrows, and numbers, which they did very well in their essays. As they did so, they were quite aware of the heteroglossic differences in the voices, styles, or stances across discourses. More importantly, they seemed able to momentarily suppress their preferred voices, styles, or stances in exchange for some incentives (e.g., academic grades).

The best example of this momentary suppression comes from Lucy's conscious style of writing in her essay. In both the pre- and post-cycle interviews, Lucy had self-identified herself as a "creative writer" who often wrote short stories in her free time. She mentioned that she was aware of the different style in writing a scientific paper and that she was not very good at it. She further explained that in writing the assignment, she had to be intentionally "boring" unlike the free-style writing she preferred:

> It's boring because I just needed to like. I knew I have to get my point across without saying like. without getting into like describing. like it

> doesn't matter what color it is. It doesn't matter if it is fun or not. Like it's just. the information, and um... I was just being very basic like.. if I was to read this out loud, I will read this in a monotone… like even in the text I was using, she was like a little more fun with it, like "she drops, the band director would commit murder" that sort of thing. But I was trying to avoid that, just because I know it was an educational text.

From Lucy's explanation, it is clear that her deliberate strategy of reducing to the basic information (which she described as boring) and avoiding the humor in her choice text was because she expected an educational text to be dry and boring. In an earlier exchange, she described an occasion where she got "marked down a lot of points" because of her free-style way of writing in an English class. Thus, that experience taught her the necessity of suppressing her own preference in free-style writing if she desired a good grade for an academic essay. Nevertheless, this does not mean that she had permanently given up her preferred ways of writing in a free style or seeing colorguard as anything but boring. She still continued to find colorguard exciting and she is currently pursuing a degree in creative writing in a state university. Rather, it was simply a temporary and calculated shifting of one's preferences and identifications at a situated point in time in order for hybridization to take place.

This momentary shifting of one's preferences and identifications to suit one's situated interest is supported by Gee's (2000) characterization of "shape-shifting portfolio youths" befitting the new capitalist world. Gee argues that today's well-off teens pick up a variety of experiences, skills, and achievements, (and I would add, voices and identifications), and are able to rearrange them dynamically and creatively for different circumstances. This characterization fits very well with my assertion that hybridization is used as a resource for such dynamic rearrangement by these shape-shifting portfolio youths. Of course, an important qualification in Gee's argument and the demographics in my sampling is that these are relatively privileged suburban youths. What this would mean for less privileged youths who are not endowed with the social and cultural capital to shape-shift will be an issue of discussion in chapter 8.

A Comparative Case from Evolution-Creationism

As a way of highlighting how hybridization could manifest itself differently, I compare Lucy's and Evelyn's case with Naomi's handling of the conflict between creationism and evolution. For this comparison, it is necessary to first discuss the different types of evidence and the corresponding claims and inferences one can make from each case. As mentioned in the beginning of this chapter, the mentoring interview with Lucy and Evelyn was the most comprehensive data in terms of documenting the process of students hybridizing their experiences with canonical physics concepts. There were also many contingent factors occurring during the mentoring interview that became instrumental in prompting the students to hybridize and/or rendering the hybridization process visible for the researcher; for example, the momentary absence of Kenneth during the conversation made it possible for Lucy's sensitivity toward the dialogic other to be displayed.

In the analysis of the conversation with Lucy and Evelyn, the evidence of hybridization came from their utterances and actions during the hybridization process itself. As such, the strongest claims about the four characteristics of hybridization were made through this analysis. For Naomi, and some other students, the evidence I have about their hybridization process were more inferential in nature based on their essays or interviews, rather than direct evidence of hybridization taking place. Likewise, my claim in the next chapter that some students did not engage in hybridization is also based on indirect evidence from their essays.

In Naomi's case, the first characteristic of hybridization – awareness of heteroglossic differences was visible in many instances through the way she positioned her responses and actions depending on who she was talking to. When she brought her choice text from *Answers In Genesis*, she was initially apprehensive about whether the teachers would reject it because there were "religious ideas in it." In her written rationale to explain why she chose this text, she simply stated that "[she] LOVE biology and human anatomy[13]" and left out the other important aspect of her choice. It was only through Kenneth's direct questioning during the interview that she gradually revealed her other reason (besides her love of biology) for choosing the article.

The interview process with Naomi also provided a telling example of her awareness of her dialogic other. Before Kenneth revealed his religious beliefs, Naomi took a cautious and formal approach in answering his questions, as could be deduced from her pace and tone in speaking. It was likely that she assumed Kenneth was not a Christian from the way she provided contextual information from the Bible and asking if he knew anything about it. Halfway through, after Kenneth revealed that he is a Christian[14], Naomi immediately became more excited and informal in her talk (which was more consistent with her usual persona). However, in another interview session when

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[13] Based on the elaborated rationale she wrote in the first cycle (the creation text occurred in the second cycle), it was unlike Naomi to write brief and vague statements for her rationale.

[14] The withholding of my religion and later revealing it halfway during the interview was deliberate on my part in order to see how Naomi would respond to the various identities I presented to her.

Brad was around, Naomi reverted back to a more reserved way of talking, especially when she was directly answering his questions.

Secondly, the hybridization characteristic of strategically and temporarily suppressing one's own preferences was also prominent in Naomi's actions as she dealt with the conflict between creationism and evolution. In chapters 4 and 5, I showed how Naomi was resistant to the ideas of evolution as it strongly opposed her biblical beliefs. Yet, despite her resistance and conviction that evolution was wrong, she managed to obtain an A for Biology and in her own admission, she "passed evolution test with flying colors." She narrated to me that if she was to take another evolution test, she would be frustrated and would critique every question in her mind, while simultaneously giving the "correct" answer as required in the test. In other words, she would suppress her preferences and dispositions consciously and momentarily for strategic reasons; that is to achieve her short-term goal of getting good grades in school. This would in turn matter to her long-term desire of getting into a medical school and eventually becoming a doctor. In the process, it is unlikely that she would have to give up her beliefs in creationism or Christianity. This balance in entertaining other belief systems while maintaining her own set of beliefs is visible in how she saw a foreseeable conflict in her career plan to be a doctor:

> I know it's going to come up and it's going to be a conflict but if I just believe in what I believe, then I know that it'll all be okay. And um.. there are obviously people who strongly disagree, and people you can't even broach and try to change them…So I think it may come as an issue, but I don't think it will be a huge issue, it will just be like "I believe."

Thirdly, the characteristic of shifting one's identification to the dialogic other's position and way of thinking was less obvious in Naomi's example. This characteristic only manifested, to some extent, toward the end of the second cycle in Naomi's evaluative writing after much dialogue between her and the teachers. Initially, Naomi was rather polarized in her views toward the way science is taught in schools. This was seen in one of her comments that the secular educational system, together with evolution, had eroded the biblical beliefs of many Christians in the U.S. As illustrated in chapters 4 and 5, I had traced the voices to those she appropriated through the readings from her creation class. Through several conversations, Kenneth and Brad then attempted to help her understand the reason why scientists talk and write in a certain way. In her final essay, there were clues to suggest she was able to shift her identification momentarily between a believer and science learner in order to consider the point of view from science[15]. (These evidence will be further presented in chapter 7 as I analyze the evaluative essays of all the students.)

Lastly, the characteristic of juxtaposing multiple voices in one's utterances to synthesize different knowledge perspectives is notably missing in Naomi's case. This lack of manifestation can be explained by two possibilities – one ideological and the other pedagogical. Ideologically, there is a big difference between the sports-mechanics gap that Lucy and Evelyn went through and the creationism-evolution gap confronting Naomi. Not only is there a long history of conflict between science and religion, there is also a lot more at stake, politically, socially, and religiously, in adopting either view. As such, it is difficult to imagine how a 15-year-old adolescent can synthesize the contrasting perspectives within a short period of time. Pedagogically, there was also no

[15] It is possible that this manifestation in Naomi's shift in identification could be her attempt to simply replicate what the teachers had told her in order to get a good grade (a manifestation of the strategic suppressing of preferences characteristic I have discussed earlier), and may not represent her genuine beliefs to consider the dialogic other's "secular" point of view.

requirement in the text assignment for Naomi to synthesize multiple knowledge perspectives the way Lucy and Evelyn did. This was because the physics topic of electricity does not deal explicitly with the origin of life or the universe. Hence, in her explanation of a self-identified phenomenon in her choice text (about the movement of nerve cells through electrical polarization), there was no need for her to talk about her knowledge and beliefs about creation, let alone synthesize them with what she had learned about electricity in physics.

In sum, the comparison of Lucy and Evelyn's examples with Naomi's provides a more nuanced understanding of the various characteristics of hybridization. While hybridization in general involves the mixing of multiple voices in one's understanding of the natural world, how it manifests itself depends on circumstances. First, it may be useful to consider different degree of hybridization according to how various characteristics of hybridizations were achieved. From Lucy and Evelyn's example, it would seem that the juxtaposition of multiple voices for knowledge synthesis represents the most developed form or level of hybridization. Tracing the genetic development of their talk that led them to this knowledge synthesis level, it is reasonable to argue that knowledge synthesis is predicated on the conditions from the previous two characteristics of hybridization – awareness of heteroglossic differences and shifts in identifications. Similarly, it is likely that the first characteristic of being aware of heteroglossic differences may represent an early form of hybridization, in which there is potential for it to be developed into the later forms. More research will be necessary to further illuminate these finer details in understanding the mutual relationships among the various characteristics, and how they are manifested in a greater variety of examples and settings.

Hybridization & Related Theories

The process of hybridization has several similarities with other constructivist theories of learning, particularly in the way the participants synthesized and collaboratively built knowledge as a group. However, there are also notable distinctions such that hybridization is a unique phenomenon from other concepts like scaffolding or conceptual change. These distinctions can ultimately be traced to the theoretical differences among Bakhtin, Vygotsky, and Piaget. In this section, I elaborate some of these similarities and differences, and also evaluate their mutual complementarity and compatibility.

Vygotskian Scaffolding

In the earlier analytical segment that showed the progressive development of ideas built through the back-and-forth exchanges among Lucy, Evelyn, and Kenneth (summarized in Figure 19), many connections can be made with Vygotskian notions of social learning, particularly scaffolding[16] and zone of proximal development (ZPD). Within this "zone", Kenneth clearly played the role of an experienced adult in scaffolding Lucy's and Evelyn's "prior knowledge" (as their textualized experiences) into a more systematic and institutionalized form of knowledge. Vygotsky (1986) called these two forms of knowledge "spontaneous concepts" and "scientific concepts" respectively. Using a Vygotskyian lens, it can be shown that the students' later ideas about forces or free fall were more developed through the scaffolding process with Kenneth. In this

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[16] Although the term was never used by Vygotsky (it was coined by Jerome Bruner in the 1950s), the process and support in which an adult mediate a child's learning through a ZPD has come to be termed "scaffolding."

regard, there is potential in connecting hybridization with a Vygotskian approach, particularly for researchers who are concerned with understanding how prior knowledge or experiences can be harnessed for learning under the conditions of a ZPD.

The close similarity between hybridization (based on Bakhtin) and Vygotskian ideas can be attributed to the two theorists' parallel socio-centric attention to language and knowledge development. The similarity of their intellectual ideas can also be traced to the influence of Marxism and post-revolutionary Russia in both theorists' lives. Because of their shared intellectual background[17], Vygotsky's dialectics and Bakhtin's dialogism have often been compared with each other. Several scholars (e.g., Holland, Lachicotte, Skinner, & Cain, 1998; Wells, 1999; Wertsch, 1991) have also integrated both theories in their theoretical approach. From this close connection, it is not surprising to see the similarity between hybridization and scaffolding. In particular, both theoretical lenses highlight the role of the "other" (dialogic or experienced adult) in dialoguing or scaffolding a student's development through a third space or ZPD respectively.

However, a key distinction between scaffolding and hybridization is the direction of crossing the different discourses. Scaffolding invokes a one-way direction to bring a student's existing ideas into a more developed robust idea. By contrast, hybridization is a two-way back-and-forth negotiation of ideas, preferences, and identifications as the students navigate the discourses. Thus, it foregrounds the agency of the students in their continuous straddling between discourses in a fluid, dynamic, and strategic manner. Furthermore, there are important elements that are not captured by scaffolding. For example, scaffolding does not explicitly deal with the affective conflicts students had

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[17] Although Vygotsky and Bakhtin were contemporaries in post-revolutionary Russia, there is little evidence that they had corresponded with each other.

toward school science discourse. As I have shown in the last two chapters, the affective dimension (e.g., students' attitudes) was deeply embedded in their social affiliations to certain communities and linked to voices and identifications. Thus, by explicitly dealing with the shifts in voices and identifications, hybridization provides a way to account for the students' positive or negative attitudes toward different ways of representing the natural world, apart from the conceptual conflicts.

Nevertheless, scaffolding and hybridization are compatible theories that can be used complementarily to enhance our understanding of learning. In my approach, although I did not foreground Vygotsky's ideas explicitly, two elements that had influenced my analytical emphasis were notably influenced by Vygotsky: the use of a genetic developmental approach and an attention to concept formation. These two elements are not frequently emphasized by researchers using a Bakhtinian framework. This thus suggests a potential bridging point between both theoretical approaches and the harnessing of their relative strengths. In particular, hybridization draws attention to the agency, resourcefulness, and willingness of the students in negotiating discourses, while scaffolding highlights the development of concepts formed in an interpersonal plane and subsequently "internalized" to a learner's intrapersonal plane. In my micro-genetic analysis of Lucy and Evelyn, I have shown how both of these aspects occurred at the same time in a mutually constitutive way. In this sense, it is possible and highly desirable to use both Vygotksy's and Bakhtin's ideas to analyze how young people learn. This synthesis will be valuable for researchers who are examining aspects of group cognition, collaborative learning, concept development, and third space.

Conceptual Change Theory

Another comparison to highlight the distinction of hybridization is conceptual change. Beginning since the 1980s, this theory has been popularly used in examining learners' existing conceptions (variously called mis-, alterative, everyday, naïve, and prior conceptions) and the mental reorganization required for them to gain acceptable and more sophisticated scientific conceptions. Albeit with minor variations, the main mechanism of conceptual change was explained by Piaget's (1964) assimilation and accommodation model (Posner, Strike, Hewson, & Gertzog, 1982). Assimilation is the gradual and stable modification of one's mental model, while accommodation is the more radical restructuring of these mental models, or more precisely called ontological categories (Chi et al., 1994), framework theories (Vosniadou, 1994), or p-prims (di Sessa, 1993).

For many Piagetians, an important condition for accommodation is that it must be initiated by *cognitive dissonance*, or the foregrounding of two conflicting ideas. Thus, this is why educators should elicit children's existing conceptions so that they can openly see the dissonance between their prior conceptions with scientific ones, and through this process, accommodate the new scientific conceptions better. This seems parallel with my thesis that the conflict created through the juxtaposition of different discourses could lead to hybridization, and hence an "accommodation" of scientific ideas. As such, this may be the overlaps or connections between the two perspectives.

However, similar to the earlier discussion, a crucial distinction in hybridization is that it takes into account the affective dimension of the students' attitudes, voices, identifications, stances, dispositions, and habitus, and this affective dimension is further tied to their membership and social affiliation to their communities. Thus, the conflict that I observed in my study was not an individual's cognitive dissonance or a psychological-attitudinal difference of opinion, but was fundamentally tied to a broader conflict among competing socio-political communities and ideologies. By contrast, following a neo-Kantian separation of the mind and emotion, conceptual change research tends to focus mainly on individual cognition isolated from socio-cultural influences.

Naomi's case is a good example of conceptual change's theoretical limitation in a situation where a person's way of knowing is deeply linked to her social identity and emotional being. According to conceptual change's premise, in order for her to understand evolution, she would have to adjust her prior conceptions about creation learned throughout her church life before accommodating the new scientific ideas. This would lead to two possibilities: either reorganized her ideas of a six-day creation by a divine being or failed to master the concept of evolution. Neither of this happened. Instead, she obtained an A for an evolution test and overall for Biology, she still aspired to be a surgeon, and she could maintain a religious stance against evolution and its teaching. Therefore, on these matters, hybridization gives a more nuanced and fluid view of how a person managed life and learning in their full complexity and contingency.

Current views of conceptual change have increasingly recognized the dynamic, situated, and constantly changing nature of conceptions (Treagust & Duit, 2008). This is also in line with new developments in situated cognition and what Klein (2006) calls the second generation of cognitive science. Along with these new ideas, the view of hybridization that I had described offers a valuable insight for this constantly developing field and its contribution to science education. This is particularly so in the affective dimension, which conceptual change researchers are increasingly paying more attention to. Thus, as Treagust and Duit (2008) have argued, there is a need for a multi-perspective approach to complement conceptual change research in order to understand the full complexity of science learning.

Summary: Hybridization as Means of Navigating Discourses

As students juxtaposed multiple discourses set up through Text-Synergy, hybridization provided a means for some of them to navigate the gap and conflict between them. Through the analysis of Lucy's and Evelyn's attempts at explaining a colorguard toss "like a physicist", I presented four characteristics that further our understanding of the intricate process of hybridization. The first characteristic is an awareness of heteroglossic differences in the use of language, and was best demonstrated by Lucy's keen awareness of the camera as the "dialogic other" and her subsequent translations for this other. The second characteristic involves a shift in identification toward the dialogic other's way of talking and thinking. This was first shown by Lucy enacting an I-R-E sequence like a teacher-facilitator, and then Evelyn's reflection on the dialogic other's expected response, which further prompted her to raise and answer questions they would not typically ask (e.g., Why one hand has more force? How does a dip work?).

The third characteristic is a juxtaposition of the dialogic other's voices in collaborative knowledge synthesis. Particular instances of such juxtaposition included the intertextual mix of colorguard terms and gestures with physics vocabularies (e.g., dip, release, momentum, energy) within a few utterances, and the semantic-gestural textualization of colorguard tosses with the visual system of physics. Consequently, such juxtaposition allowed them to synthesize various perspectives, as was shown by the progression of ideas through the back-and-forth movement of corrections, adoptions, and revoicings across the various people and their discourses (e.g., Figure 19). Finally, the students' motivation in reaching out to the dialogic other and their devising of strategies to fulfill their assignments provides the basis for the fourth characteristic of hybridization: the strategic and temporary suppression of one's preferred voices for short-term benefits and goals. This was best seen in their essays where they suppressed their preferences and identifications (e.g., non-reductionist stance, free-style writing, creationist beliefs), and "shape-shifted" themselves to mix the dialogic other's voices into their spoken and written utterances, in order to obtain better grades.

In the next chapter, more evidence of hybridization in other students' essays will be presented to further support and extend these characteristics of hybridization. While this chapter has shown the value of hybridization in facilitating Lucy's and Evelyn's navigation of discourses and their subsequent synthesis of knowledge, the next chapter highlights another benefit of hybridization: it created the opportunities to foster critical literacy in evaluating how science is represented across different discourses.

Chapter 7

Fostering Critical Literacy through Hybridization: The Outcomes of Hybridizing Understandings

In chapter 6, I showed how the process of hybridization and knowledge construction for two students developed as they mixed two different voices during a conversation with Kenneth. Through a detailed analysis of this process, I illustrated four characteristics of hybridization that were instrumental in facilitating them to develop better conceptual understanding of physics principles. I also showed how they strategically managed the requirements of their assignments by dynamically shifting their preferred voices and identification for hybridization to take place.

In this chapter, I examine further evidence of hybridization from all the students' assignments. The first part of the assignment requires the students to write a scientific explanation "like a physicist", while the second part requires them to critically evaluate how the representation of science in their choice texts differed from the textbook. I then examine the relationship between these two parts and explain a key finding that the use of a hybrid voice in the explanation generally created opportunities in fostering critical literacy in the evaluation. Furthermore, I also look at the impact of hybridization on the students' attitudes toward school physics through the survey results, and present this chapter's second key finding: female students in general made a stronger connection between their interests and physics due to Text-Synergy compared to male students.

Explanatory Writing

Coding of Discursive Modes

I first examine the degree of hybridization exhibited in the first part of the student assignment, which is the explanatory writing. I developed a coding scheme to categorize all the student's explanatory writing into three identified discursive modes: non-school, mixed, and school-based. This is based on how they juxtaposed various voices in their explanations, where voice is analyzed in terms of the four semiotic-technological systems (i.e., semantic, visual, spatial-temporal, intertextual). These various voices can be explicit (manifest intertextuality) or implicit (constitutive intertextuality), and could come from a variety of external sources, including the voice of the choice text's author, the textbook, or the student himself/herself.

This division of discursive modes is not distinctively categorical, but rather along a continuum. On one end, non-school discursive modes are instances where the out-of-school and personal voices of the student were predominant in the explanation. Although the scientific voice (e.g., physics terms, equations) was used in some parts of the essay (because they had to meet the given assessment rubric), these voices were distinctively *incorporated* (Fairclough, 1995a) and subsumed into the voice of the student. An exemplar can be seen from Jimmy's informal introduction of the idea of *Joule* (a physics term) to his reader: "So now that you have your answer, I bet you're wondering what a 'J' is." On the other end, school-based discursive modes are instances where the scientific voice dominated in the explanation in the sense that the student *assimilated* (Ivanic, 2004) his/her voice into the scientific voice. These modes are easily distinguished by the students' attempts to paraphrase the formal language used in their prototypical science texts. (Students in the school-based discursive mode tend to have choice texts that are written by scientists or science educators.)

In between is what I call a mixed discursive mode where both voices were positioned on a more equal footing. This mixed mode exemplifies the type of hybrid utterances that were shown throughout the micro-genetic analysis in chapter 6. In a sense, this continuum can be seen as a degree of how much the personal voice (a) dominated, (b) shared, or (c) gave way to a scientific voice, and vice versa. Furthermore, the degree of hybridization increased as both voices were mixed and decreased as one voice dominated or gave way to the other. This relationship can be illustrated in Figure 21.

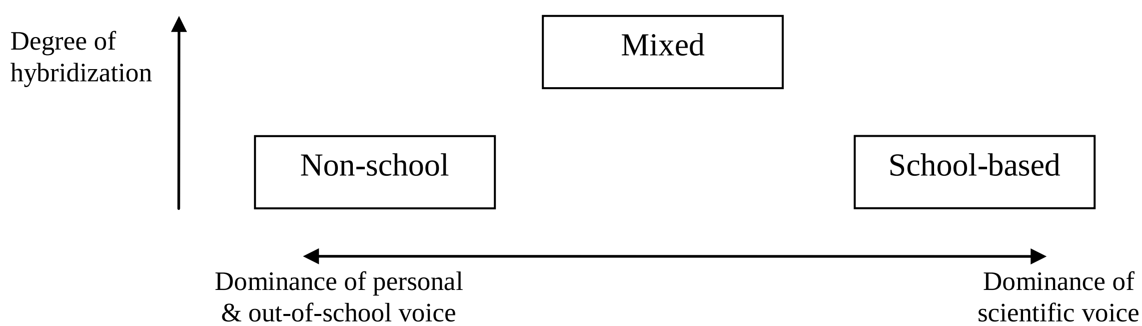

Figure 21. Continuum of the three discursive modes in relation to (a) the degree of hybridization, and (b) the dominance of voices.

Based on a preliminary analysis, I identified several key linguistic and representational characteristics as criteria for each discursive mode, and some examples to exemplify each mode. These characteristics were tested and discussed with a second rater, and revisions were made after the discussion. Using the finalized rubric as shown in Table 8, I then coded all the essays from the two cycles, while the second rater coded a randomly-selected representative sample (20%). The inter-rater reliability, based on proportion of codes in agreement over the total number of codes, was 83%.

Table 8. *Characteristics and Examples of Discursive Modes*

Discursive Mode	**Dominant Characteristics**	**Examples**
Non-school	Out-of-school and personal voices dominate over scientific voice, e.g., • Using extensively first or second person pronoun, e.g., . you, I, we • Narrating problem solving procedures with future verb tenses (e.g., will, need to) and material processes (e.g., find, get) • Using informal tone or language • Using mainly realistic photographs	So now that you have your answer, I bet you're wondering what a 'J' is (Jimmy) Next find person one's weight the same way, assuming that his mass is 85 kg. You will find that he weighs 824 N (Naomi)
Mixed	No dominant unitary voice. Frequent occurrences of hybrid utterances, e.g., • Juxtaposition of multiple voices within 1 clause or in consecutive clauses and/or sentences • Mixing of non-science and physics visual systems	**Impulse and momentum** are two key concepts affecting the distance a golf ball travels. Together they define the "power" a ball has while moving through the air. For golfers, this means that to achieve more final momentum, you have to hit the ball with either something more massive, or something moving faster, for a longer period of time (Cody; **bold** and "quotation marks" in original)
School-based	Scientific voice dominates over out-of-school and personal voices, e.g., • Formal encyclopedia-like language • Generic "timeless" references (e.g., present tenses, generic object/places) • High lexical density and nominalization • High modality (truth value) • Omission of human agent and appraisal words • Extensive use of abstract diagrams and graphs	The diagram to the left is a bird's eye view of a curving soccer ball. It shows how the ball spins on an axis perpendicular to the air flow across it…. Therefore, an imbalance in forces is created and the ball spins and curves. This deflection is also called "Magnus Effect" (Sabrina)

Evidence of Hybridization

From chapter 6, one of the major characteristics of hybridization is the juxtaposition of multiple voices to synthesize knowledge across perspectives. This characteristic can be seen[18] in the students' explanations categorized under the mixed discursive mode (about one-third of the class). As a continuation from the previous chapter that showed a micro-genetic development of Lucy's ideas, I show an excerpt from her written explanation to illustrate how she juxtaposed the voices from colorguard and physics:

> When an equal *forge* (sic) is *exerted* with both hands, the rifle rotates in place and the result is a *single*. A *single* is when the rifle makes one rotation before being caught at the same height it is released. Likewise a *double* makes two rotations, a triple *three* and a *quad* makes four. (*italics* added)

Like the episode where Lucy, Evelyn, and Kenneth collaboratively built their knowledge by moving back-and-forth across discourses, Lucy's writing exhibited a similar mixing of voices within a sentence or consecutive sentences in two ways. The first was a juxtaposition of terminologies and definitions from colorguard and physics, such as "force", "single", and "double", and their definitions. The second was a mix of her textualized tossing experiences (e.g., coordination of left and right hands) with a free-body diagram and mathematical relationships (not shown here; see Appendix I).

In addition, several students' explanations also show evidence of another characteristic of hybridization – the awareness of heteroglossic differences. This can be

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[18] In the previous chapter, I had explained that the evidence on hybridization from the students' essays were inferential rather than direct evidence of hybridization actually taking place, as was the case for Lucy and Evelyn during their conversation with Kenneth.

seen from the use of *boundary maintenance* markers (Fairclough, 1995b) to explicitly indicate different discourses. For instance, in Cody's explanation as shown below, he consciously marked terms from golf discourse with quotation marks (e.g, "club head speed", "power") and physics vocabularies in bold (e.g., **force**, **kinetic energy**, **impulse**, **momentum**). Cody's distinction was particularly notable given that the word "power" is also a common physics vocabulary that was taught in the mechanics unit. Thus, his recognition and distinction of "power" as a golf term in this context showed his awareness of the heteroglossic use of words in different discourses.

> The "club head speed" is basically how fast the golf club is traveling when it strikes the ball. The distance a ball travels is a result of how much **force** is applied to it by the golf club... This is achieved by the transfer of **momentum**, as well as the transfer of **kinetic energy**. **Impulse and momentum** are two key concepts affecting the distance a golf ball travels. Together they define the "power" a ball has while moving through the air. (**bold** in original)

The characteristics of hybridization were less visible in the students' explanations categorized under the other two discursive modes. For students who wrote using a school-based discursive mode, the main reason for this is because they had found a prototypical scientific text that explains their self-identified phenomenon. Thus, they were merely paraphrasing the explanation in that scientific text[19], without plagiarizing (with the exception of one student). Thus, in the process of such *assimilation* (Ivanic, 2004), the scientific voice was dominant and there was little hybridization.

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[19] Because of such paraphrasing, students who wrote using a school-based discursive mode were not necessarily better students in terms of writing scientifically or having deeper conceptual knowledge.

Critical Evaluation

In this section, I move on to the next part of the student assignment: the critical evaluation of the choice text in comparison to the physics textbook. For this requirement (see Appendix F), each student was asked to write about three of the following options:

(a) Evaluate the type of representations (e.g., vocabularies, diagrams, measurement units) used by the author in relation to the textbook.

(b) Evaluate the communicative styles (e.g., tone, expression, stance, humor) used by the author in relation to the textbook.

(c) Critique the major errors or biases made by the author.

(d) Reflect on personal learning experiences through the assignment.

(e) Summarize a portion of the text to make it more accessible.

For the purpose of this chapter, I will only focus on the first two options (representation and communicative style). One reason is because the majority of the students chose these options, thus providing sufficient sample size for later quantitative analysis. The percentages of students who did the first option were 80.0% and 79.3% for the first and second cycle respectively, while the percentages for the second option were 56.7% and 41.4% for the first and second cycle respectively. More importantly, these two options correspond with the presentational and orientational dimensions of meaning (Lemke, 1998a; see chapter 2). According to Fairclough (1995a), these two meaning dimensions must always be analyzed to understand the critical discursive nuances in a text. In the design of Text-Synergy as a third space, besides making a stronger connection between physics and the students' interests, part of the goal was also to enable students to become more critical in what they read about science in both their out-of-school activities and the classroom. Thus, the design of these two options in the assignment was geared toward helping the students critically analyze their texts in terms of the texts' representations and communicative styles.

Coding of Evaluation

For this analysis, I developed a 3-point scoring rubric to assess the students' evaluation in three different categories. The first category, called authorship, assesses the student's evaluation of the author's purpose in relationship to the targeted audience. An evaluation was scored as 0 if the student did not specify the author, audience, or author's purpose. If one of these (author, audience, or purpose) was identified, it was scored as 1, and for any two identified, it was scored as 2. A score of 3 was given if the student not only identified at least two of the author, audience, or purpose, but further stated why the author wrote in a certain way according to the identified purpose. This category of authorship was universally coded for every student regardless of the options they had chosen in their assignment.

The second category, representation, assesses the student's evaluation of the different usage of representations in relation to the author's purpose. This category is only coded for students who did this option in their assignment. An evaluation was scored as 1 if the student briefly stated the similarities and differences in how the representations were used in their choice text, and 2 if he or she contrasted the similarities and differences to a greater degree, such as giving more variety and examples, or relating them with the representations in the physics textbook. A score of 3 was given if the student not only made the contrast, but went on to account for it in relation to its purpose. Unlike the first category of authorship, there is no score of 0 in this category because the students could choose not to do this option.

Lastly, the scoring for the third category, communicative style, is almost identical to the second category of representation. A score of 1 and 2 were given for varying degree of contrasting the communicative styles, while 3 was given for those who not only made the contrast, but further accounted for it in relation to its purpose. Similarly, there is no 0 score in this category. Table 9 summarizes the criteria for each category – authorship, representation, and communicative style, and their corresponding exemplars.

Table 9. *Scoring Rubric & Exemplar for Critical Evaluation*

Authorship

Score	Criteria	Exemplar
0	Unable to identify author, audience or purpose	
1	Identify one of (a) author, (b) audience OR (c) purpose	The purpose of this is to not overwhelm the reader with advanced terms and ideas, but give a more comprehensive explanation to further expand the ideas. (Jason; purpose only)
2	Indicate TWO of (a) author, (b) audience, or (c) purpose	The text that I found was created by a high school student for a physical science project (Evelyn; author & purpose)
3	Indicate author/audience and purpose AND explain further why author wrote in a certain way according to the identified purpose	This text was broadcasted on a sports news network, and a physicist explained how the goal was possible. Because their audience was mainly sports enthusiasts, the physicist used a lot of visuals, and only explained the simplest factors for the goal. (Haley)

Representation

Score	Criteria	Exemplar
1	Briefly contrast similarity or difference between representations	Uses quotes from Dr. Michio Kaku who mentions “energy”, “wormholes”, but other than those two words and “electromagnetic”, physics terms are not discussed (Jack)
2	Contrast similarity or difference between representations to a greater degree (e.g., more variety, examples, or contrast with physics text)	It uses very detailed and complicated automobile terms like weight per filly, torque, sandbagging… Although the article does use many physics terms like acceleration, velocity, momentum, it doesn’t include words like displacement, friction… It shows many pictures of the Ferrari 430 Scuderia in motion along winding roads and on the tracks but it only includes four education pictures and graphs (Hanks)
3	Contrast similarity or difference between representations AND evaluate those differences with respect to audience or purpose	The reason for this is because Shot Science’s goal was to educate basketball players who are looking to improve their shot. Most basketball players are not necessarily scientists, so they could understand these terms easier. The textbook on the other hand uses more precise physics vocabularies so that we can use them to do calculations (Mike)

Communicative Style

Score	Criteria	Exemplar
1	Briefly contrast similarity or difference between the communicative styles	The author does have a good sense of humor which is good because he can relate physics to BMX while having fun. The first example of his humor is in the title of the text. The title of the text is “The physics of humiliation” (Zac)
2	Contrast similarity or difference between styles to a greater degree (e.g., more variety, examples, or contrast with physics text)	The tone of the article is unlike the textbook because in the textbook, it uses very precise scientific vocabulary, while the article uses different synonyms for the same words. Also, unlike the textbook, the article uses informal diction to explain the feelings of the audience when… (Sofia)
3	Contrast similarity or difference between styles AND evaluate those differences with respect to audience or purpose	The formality the speech in my article doesn’t change much from any other magazine article I’ve read. It is a somewhat dry sounding language and is aimed directly toward the magazine’s audience therefore it is fulfilling its purpose and has done what it was meant to do, grab the car enthusiasts attention and have them read on (Hanks)

Similar to the procedure explained in the earlier section on explanatory writing, the criteria for this scoring rubric were tested and discussed with the same second rater, and one round of revisions was made after the discussion. I scored all the evaluations from the two cycles, while the second rater scored a randomly-selected representative sample (20%). The inter-rater reliability for this coding was 86%.

Exemplars of Critical Literacy

As a way of understanding how the students evaluated their choice texts critically, I highlight and explain several exemplary evaluations from students who scored 3 in all three categories. I will also point out evidence of hybridization found in these evaluations. The first set of exemplars comes from three students (Joe, Ben, and Mike) in the first cycle who chose a commercial video for their choice text; two from the TV series *Sport Science* that featured football and one from a website called *Shot Science Basketball*. As these videos explore the relevance of physics involved in a sports action, such as a football bull run and a basketball free throw, they have very much in common with one another. Not surprisingly, Ben and Joe were in the school football team, while Mike was in the basketball team.

What stood out in these students' evaluations was how they recognized the differences between the expectation of the video's targeted audience and that of scientists or science learners in general. One reason for this has to do with how their experiences and identifications were embedded in the sports, which led to their intimate understanding of the targeted audience of players and fans. Besides being football and basketball players themselves, all these students had (according to their journal postings) also watched these videos prior to the commencement of Text-Synergy. In other words, they *were* the targeted audience of these videos. However, as they started learning physics, they also began to identify with scientists or physics learners and consider their views and expectations. This shift in identification by putting oneself in someone else's position is one of the characteristics of hybridization I discussed in the previous chapter. Such shift in identification was what prompted them to compare the representations and communicative styles they used to see as sports players with those they were learning to see as physics learners. The following exemplar from Mike illustrates this contrast (note the use of pronouns in his evaluation, e.g., *we, our, they, their*):

> This video titled "Get Perfect Shooting Arc" was made by "Shot Science." It has a mixture of basketball terms such as: arc of the basketball, following through, elevate, flat shot, flat rebound, and the iron (rim)… However the video does not use other terms *we* have learned in *our* text book such as velocity, projectile, and the change in distance vertically. In exchange for these terms, the video uses speed, basketball, and height. The reason for this is because Shot Science's goal was to educate basketball players who are looking to improve *their* shot. Most basketball players are not necessarily scientists, so *they* could understand these terms easier. The textbook on the other hand uses more precise physics vocabularies so that *we* can use them to do calculations (*italics* added)

In this contrast, Mike pointed out the different audience and purpose, and how these account for the different terminologies used. His evaluation demonstrated his intimate knowledge of basketball terms and what basketball players do, and this became useful as he drew on this knowledge to explain the use of non-technical terms in comparison to what he described as "precise physics vocabularies [used] to do calculations." Mike's choice of pronouns and grammatical agents were revealing in how he constructed his identification in this evaluation. Despite being a school basketball player himself, he referred to them in the third-person of "basketball players", "they", and "their." By contrast, his use of "*we* have learned" and "*our* textbook" signaled his identification as a physics learner as he was writing the essay. This shift in identification thus allowed him to step back and evaluate the different language between the video and what was taught in class.

Another common characteristic in these exemplary essays was how they critiqued the physics textbook as “boring”, “monotone”, “bland”, and “less enticing.” This comparison was made because of a sharp contrast with their videos, which were described as “humorous”, “suspenseful, “captivating”, and “phenomenal.” Yet, as they accounted for this contrast, they were able to give reasons for the use of such discursive moves in scientific communication, instead of simply labeling them as “boring.” Joe, for example, counter-argued that the textbook was “precise”, “straightforward”, and “strictly factual.” Mike also argued in the earlier excerpt that “the textbook on the other hand uses more precise physics vocabularies so that we can use them to do calculations.” He then went on to explain while the textbook was “less enticing”, it does “a better job at presenting the right information”, as shown in this excerpt:

> On the other hand, I feel that the textbook does do *a better job at presenting the right information* on the graph, by giving you a motion diagram, velocity, and time. The textbook *may be less enticing*, but if you have a broader sense of physics it *really helps you understand* the trajectory of the basketball.

The second exemplar I want to highlight is Naomi’s comparison of *Electrical Design* from Answers in Genesis and *Conduction* from an AP physics text. (I had analyzed both texts in detail in chapter 5.) Naomi divided her elaborated evaluation into three paragraphs, each focusing on a different requirement of the assignment: representation, communicative style, and personal reflection. In both the representation and style, Naomi made several contrasts between the more “conversational” *Electrical Design* with “simpler vocabulary written in first person” and the “more complicated, scientific, and written in third person" *Conduction*. She was also able to identify the purpose of *Electrical Design* in comparison with *Conduction*:

> The author was definitely trying to prove a point, and it was not from a physics standpoint. The author was trying to convince the *reader* that there was a creator behind the entire nervous system in humans, God... The author did a great job of supplying a simple explanation and opinion for an average *reader* who wants to know that there is a creator behind the electrical design in humans, and a basic understanding of that design (*italics* added).

Based on my interview with Naomi, her dual identifications as a believer and science learner was important in getting her to point out the different purposes and the "different angles" and ways of "presenting information." Just like Mike earlier, despite being the targeted audience of *Electrical Design*, Naomi constantly referred to a generic "reader" and did not identified herself as a believer in the paragraph shown above. This was deliberate because she needed to distance herself from being a subjective audience as she evaluated the representational and communicative features of *Electrical Design* and *Conduction*. However, in a later paragraph on personal reflection, the identification of a believer became more prominent as shown here:

> I also learned a lot about my faith. I have attended church almost all of my life and have always believed in the bible, but this article proved to me just another reason why I believe in Jesus... It's difficult to believe that our delicate nervous system that still puzzles most neurologists today, came about by evolution. This text piece from answersingenisis.com gave me yet another reason why I put my faith and trust in God.

While Naomi indicated her stronger faith after reading *Electrical Design*, this does not imply a more negative view toward *Conduction* in particular and science in general. In fact, Naomi expressed several times during the interviews about how she really liked *Conduction* as it was more thorough and comprehensive in explaining the underlying bioelectrical processes. Through the evaluation, she could see why the textbook omitted any reference to a creator, and concluded: “since the two text pieces are written differently, they are allowed to stress different angles and present information in various ways.”

Naomi’s conclusion above did not come from a sudden and automatic change from doing the assignment alone. Rather, it was through a long conversational process between her and the teachers on the creation-evolution debate, which I do not have the space to present in full. I will however show one brief conversation where there was some kind of reconciliation between Naomi and Brad, and the respective discourses they represented. In this conversation, Naomi first defended her view that scientific texts, particular biology and geology, were rather biased because their theories were “taught as fact.” She gave an example that “dinosaurs that roamed the earth millions of years ago” was only a theory, but this statement was always stated as a fact in science through a high modal usage (e.g., without the use of “could” or “might”). When Brad asked her why a scientist would write it this way, Naomi responded:

> Because it is worldly accepted now… it's a *worldly known fact*. Even if the author didn't go to church and they just didn't know, like they just thought it was millions of years ago. That's not their fault that they didn't know that, but *that's how far it comes to just being. shown as a fact*.

Naomi’s view of what is a fact when “it is worldly accepted” draws parallel with Latour’s (1987) notion that a scientific claim only becomes a fact when no one in the scientific community disagrees with it anymore. In Latour’s view, a fact emerges when a network assemblage of claims, data, evidence, graphs, papers, spokespersons, and laboratories is solidified into a “trial of strength” and eventually becomes “black-boxed.” This was echoed in Naomi’s response when she commented “that’s how far it comes to just being shown as a fact." In other words, scientists do not open their black-boxes anymore in their usual work and communication for old and widely accepted theories.

Certainly, the reason why Naomi would make this point was due to her membership in a religious community. Thus, the claim that "dinosaurs roamed the earth millions of years ago" cannot be a fact for her because there are many people in that community who disagree with it. Through such conversations, Brad and I took the opportunity to share with her our views about how and why science is presented in relation to its targeted audience and purpose. Conversely, as science educators, we also learned from her perspective how science teaching *ought to* be presented too. This is best shown by Brad's followed up response to her:

> Brad: so if they wrote the same article and said, 'scientists *presume* dinosaurs lived millions of years ago *due to* carbon dating [and] testing of fossil records'…
> Naomi: that would be more acceptable. Or scientists have a theory that..

In this exchange, when Brad suggested that if the "black-box" that established the age of dinosaurs through its discursive and technological-mediated practices be opened in scientific teaching, Naomi would find that "more acceptable." From an education point of view, Brad's suggestion is tenable and much desirable as it actually unpacks the process of scientific argumentation and theory-making more clearly for science learners, instead of implicitly expecting them to accept certain factual information blindly as undisputable "facts." This conversational exchange with Naomi highlights the value of a contrasting perspective for science teaching and learning. It is also one of many examples that facilitated Naomi's momentary shift in identification to consider why and how different groups of people, in her words, “stress different angles and present information in various ways.”

Overall, these two exemplars (Mike and Naomi) demonstrate the emerging development of critical literacy skills when two contrasting voices and identifications were brought together. In the sport videos case, while the students saw the textbook as less captivating, they also appreciated the need for it to be “straightforward” and “strictly factual” in order to give the reader a “better understanding of things” and to employ more “precise” language useful for calculations. On the other hand, they also distinguished that commercial-oriented media had to be different in order to “captivate the audience” and improve viewer ratings. In Naomi’s case, she understood that “the purpose and style of writing can certainly change the way a person reads a text.” Similarly, while she critiqued science textbooks as not presenting the perspective of creation, she also understood how the audience and purpose were important factors shaping the way textbooks were written.

Although it was not observed that students were able to question the underlying interests, motives, and ideologies of the authors and the social-political context in which they operate (a difficult literacy skill), I argue that they had the potential to do so. An important first step was taken when they began to understand why scientific ways of talking, writing, drawing, communicating, and acting are carried out in certain ways, instead of simply seeing them as “dry”, “boring”, or “secular.” Given more time, it is possible to develop this important critical literacy skill. This is not only essential in a digital information age, but is also crucial in addressing the disconnect that adolescents face when they compare the “colorful” representation of science/nature in today’s media with the overtly factual representation of school science in the classroom. This issue will be further discussed in the concluding chapter.

Relation Between Explanatory Writing & Critical Evaluation

This section examines the relationship between (a) the discursive modes in the explanatory writing and (b) the scores in the critical evaluation. I will first show a significant statistical relationship between these two requirements of the student assignment. This will then be followed by a textual analysis to interpret the quantitative finding, particularly why students who explained using a mixed discursive mode generally scored better in the critical evaluation.

Statistical Relationship

Descriptive statistics.

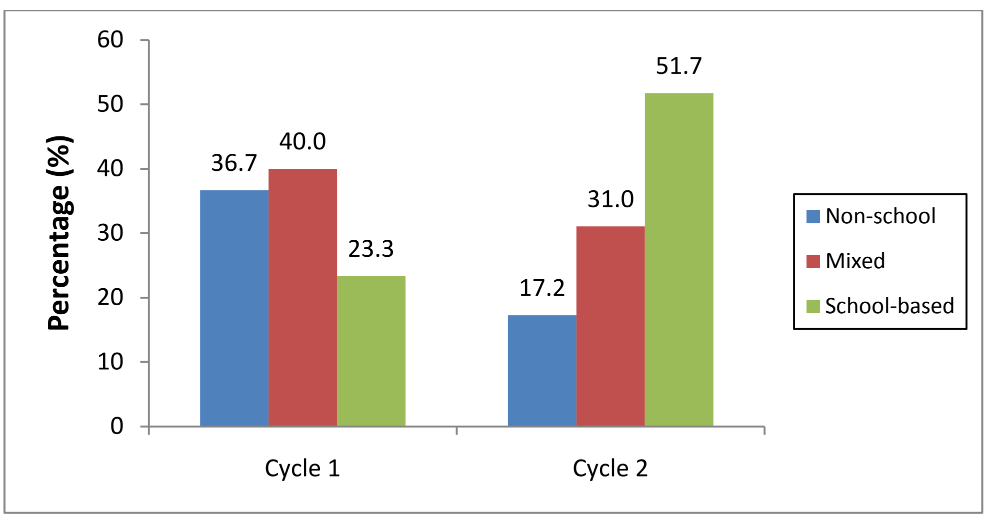
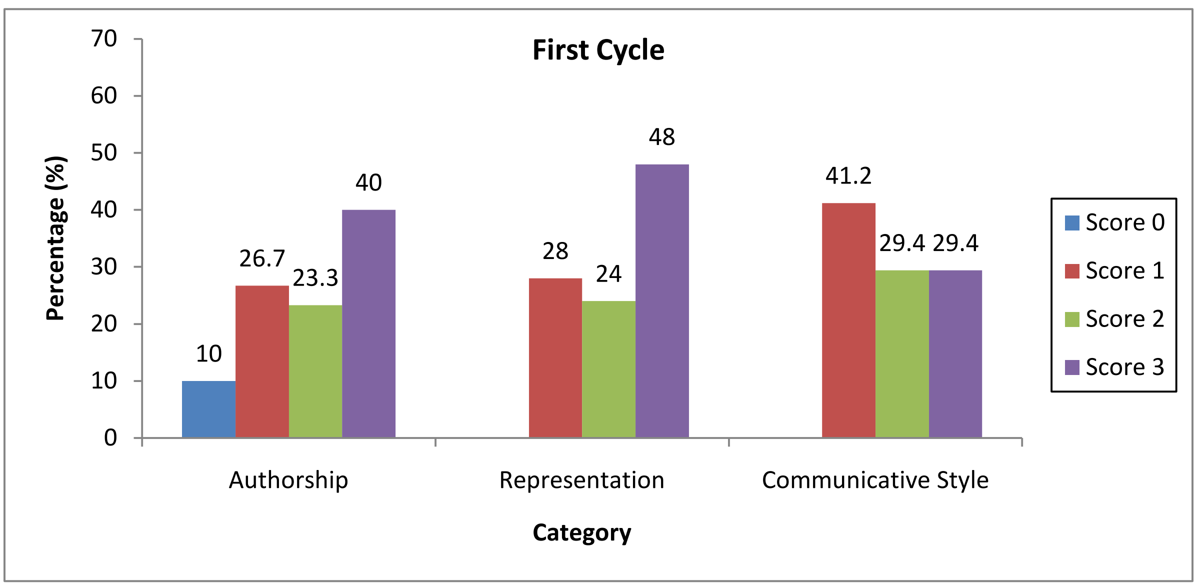


Figure 22. Distribution of discursive modes in both cycles

The frequency distribution of the three discursive modes in the explanation (non-school, mixed, school-based) is shown in Figure 22. As the graph shows, there was a shift toward a more dominant school-based voice in the students' explanatory writing as the program progressed. As I will further elaborate later, this shift was largely due to the changes in the nature of the students' choice texts from predominantly student-made texts and videos to printed information-based materials in order to suit the academic expectations of writing a school-based essay.

The frequency distribution of the scores for each evaluation category (authorship, representation, communicative style) is shown in Figure 23. As the graph shows, the vast majority of the class scored a 2 and above for every category, with 71% on average scoring 2 and above, and 42% scoring a 3.



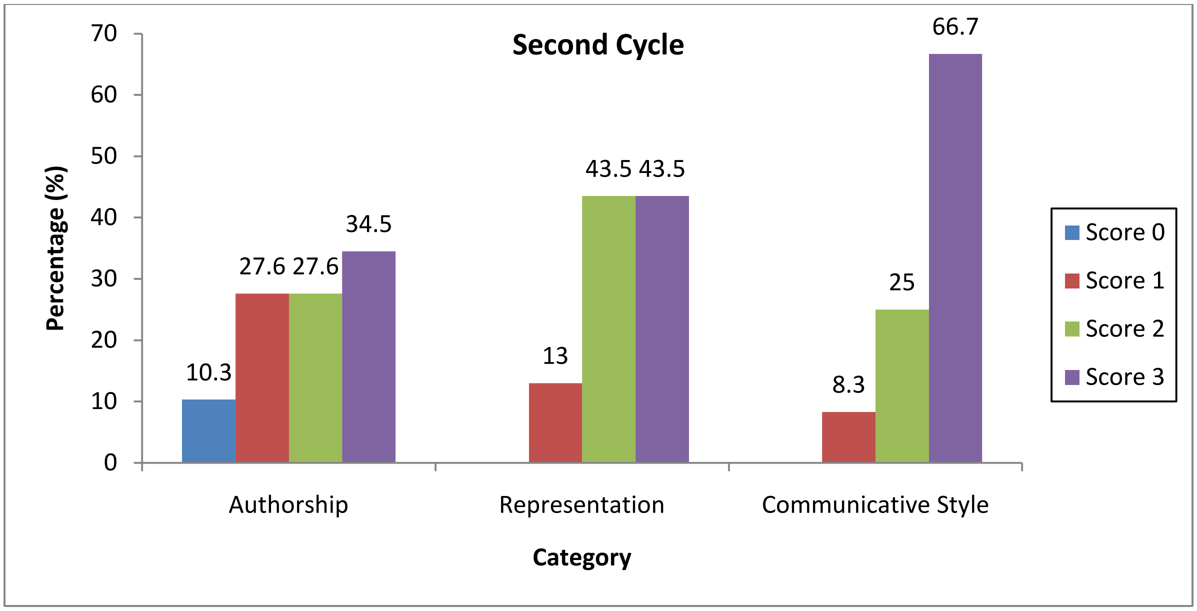


Figure 23. Distribution of evaluation scores by category in both cycles

Comparisons of Means

To examine the relationship between the discursive modes and evaluation scores, I first compute a composite evaluation score that averages[20] the three evaluative scores of authorship, representation, and communicative style. The overall means and standard deviations of this composite score are M = 1.90 , SD = 0.87 , and M = 2.06 , SD = 0.76 for the first and second cycle respectively.

Figure 24 shows the mean evaluation composite scores across each discursive mode. In both cycles, the mean evaluation scores for the mixed group were the highest among the three groups. ANOVA results show a significant difference in the means in the first cycle ($F(2,27) = 4.624$, $p = .019$). Furthermore, Tukey's HSD post-hoc test shows

[20] This composite score takes into account the fact that not every student chose the option of representation and/or communicative styles in their assignment. Thus, instead of adding the scores from the three categories and divide by 3, I divide the sum by (A+1), where A is the number of assignment options selected by the student.

the difference was significant (p = .02) between the scores of the non-school (M = 1.49, SD = .96) and mixed groups (M = 2.45, SD = .58). Although the mean for the mixed group is also higher than the school-based group (M = 1.76, SD = .96), it was not significant (p = .17) due to the small sample size. To increase the sample size, I combined the non-school and school-based groups to test the hypothesis that the score for the mixed group was higher than the two combined groups. An independent sample t-test shows the mean score for the mixed group was indeed significantly higher than the combined group (M = 1.56, .SD = .87); t(28) = 3.025, p (one-tailed) = .01. In sum, it was found that in the first cycle, students who explained using a mixed discursive mode generally had a higher evaluation composite score.

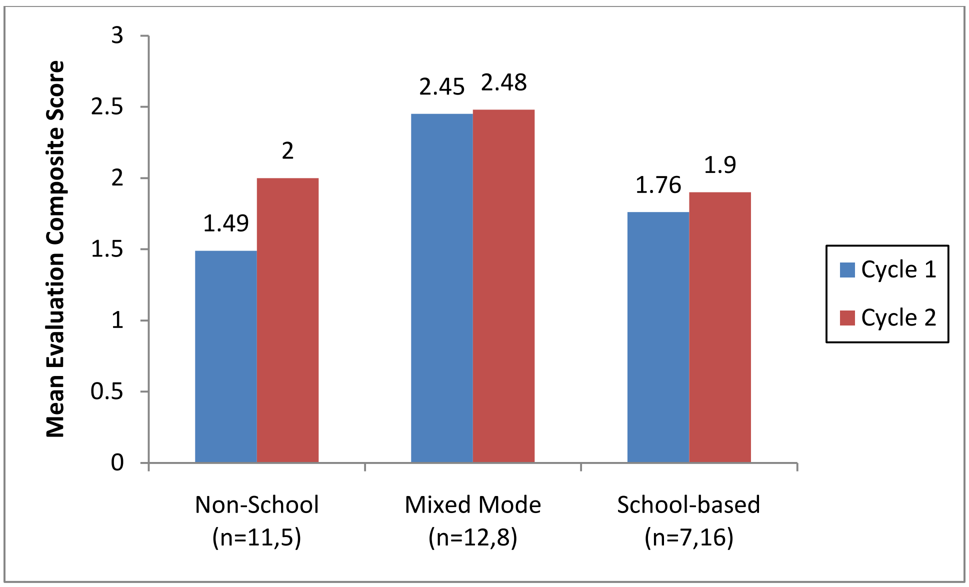


Figure 24. Comparison of mean evaluation composite scores across discursive modes.

Textual Interpretation

The earlier statistical result points to a key finding in the first cycle: students who explained using a mixed discursive mode in the explanation component of the assignment generally performed better in the critical evaluation component. That is, they were better in critically evaluating how science as represented in their out-of-school texts was different from the physics textbook. The idea of juxtaposing multiple voices can be used to explain this finding. When one voice was too dominant in the student explanation, it is likely that the authoring student became too immersed in that single voice and inattentive to its one-sidedness, thus neglecting the alternative viewpoints of the other voice during the evaluation.

This explanation can be inferred from many of the students' essays. For example, those students who explained using a school-based discursive mode (by paraphrasing their scientific texts; see earlier section) tended to simply state the informative and organized nature of their texts without making any reference to its purpose or giving an alternative perspectival representation. Because scientific language is grammatically constructed with passive voices, minimal references to human agents, and timeless universal statements, students might have found it difficult to identify the text's rhetorical structure. Conversely, those who focused on the personal and out-of-school voices in the explanation (many had chosen student-made texts) tended to discuss only the texts' accessible and sometimes humorous nature, but not the limitations of such representations and styles for scientific meaning making. In sum, without the juxtaposition of two different voices for comparison, it was difficult for the students to balance their critical evaluation.

By comparison, the exemplar evaluations from Mike and Naomi shown earlier illustrate why students explaining or dealing with multiple voices did better in their evaluation. As the earlier examples showed, the ability to shift their identifications to consider the dialogic other's perspective has helped these students appreciate the necessity for various discursive moves in different texts. This was an important step in getting them to critically evaluate the text's purpose and the way it was produced.

A direct evidence of the importance of multiple perspectives was expressed by a student himself – Hank, who also scored a 3 in every evaluation category in the second cycle. Unusually, instead of picking one choice text for the assignment, Hank went beyond the requirement and chose three different texts on the same topic (about a newly designed electric tram model). As he compared these different texts together with the textbook, he saw the benefit of having multiple publications, as he wrote:

> My articles come from opposite sides of the spectrum and everywhere in-between from credibility to style of writing. This gives a very wide view at my phenomenon and also gives a checks and balance system with all four publications.

This benefit was so important to Hank that he even put this as a suggestion for Brad in a survey at the end of the course:

> If you plan on doing text assignments in future classes I strongly suggest requiring students to pick more than one article on the same topic not only because it provides more information but it is more useful to compare the two articles than compare a single article and textbook. Although I figured this out on accident I feel it was much more beneficial to my learning.

Therefore, this relationship between the explanation discursive modes and the critical evaluation scores indicates the merit of hybridization in not only constructing conceptual knowledge across voices and identifications (as shown in chapter 6), but also in fostering critical literacy to evaluate how science was represented across various discourses. This somewhat contrasts with the dominant view that a good instructional program should assist students to write in a near perfect scientific voice as much as possible. Furthermore, as shown in Figure 22, there was a shift toward a school-based discursive mode in the second cycle (mainly due to the shift in the choice texts toward a more information-driven nature). In light of this section's finding, the shift toward a school-based discursive mode might not be that beneficial as there was no increase in the evaluation scores in the second cycle, as the next section will elaborate.

Changes from First to Second Cycle

In the second cycle, the differences among the evaluation mean scores across discursive groups narrowed, and there was no significant difference among them (see Figure 24). This non-significant result shows that the previous relationship between discursive mode and critical evaluation was either less prominent or no longer true. One reason could be because after one cycle of implementation, these students had already developed certain expectations of the assignment, including what texts to bring, how to write, what to evaluate, and most importantly how to be strategic in getting good grades. Thus, as I learned from my interviews in the second cycle, many students chose their texts based on an informed anticipation of what they could explain and evaluate. This means that by the second cycle, the relationship between choice texts, explanatory writing, and critical evaluations became much more complex than the first cycle when the students did not know beforehand the purpose of bringing their choice texts and how they would be graded.

Another reason why the differences across discursive modes narrowed was because the students might have learned certain strategies on how to evaluate their texts from the first cycle, and these accumulated over to the second cycle. Thus, even as they shifted their discursive mode from a non-school or mixed mode in the first cycle to a school-based mode in the second cycle, the effects were carried over and this resulted in the mean differences across modes narrowing.

I also compared the overall mean scores of the evaluation between the first and second cycle. A paired-sample t-test shows no significant difference between the mean scores in the first cycle ($M = 2.02$, $SD = .76$) and the second cycle ($M = 2.08$, $SD = .76$). In other words, there was no overall significant improvement in critical evaluation from the first to second cycle. Furthermore, a Spearman correlation analysis shows there is a modest correlation ($r(26) = 0.46$, $p = .01$) between the critical evaluation scores of the two cycles. This implies that students who did poorly in the first cycle generally continued to do so in the second cycle. Therefore, despite that the majority of the class did well in evaluating their choice text (71% scoring 2 and above), there was insufficient attention given to the minority that did not perform as well. On hindsight, there were few measures taken to assist these students after they got back their first essays and prepare them for the next cycle. In addition, the scoring rubric that I used in this chapter was not yet developed then, and Brad’s grading of their essays was rather cursory due to the time constraint we faced. As such, during the course, we were not able to effectively identify those students who under performed in this category and help them improve. Nevertheless, subsequent iterations of Text-Synergy would benefit from this finding and insight.

Attitudinal Findings

Changes in Attitudes Toward School Physics

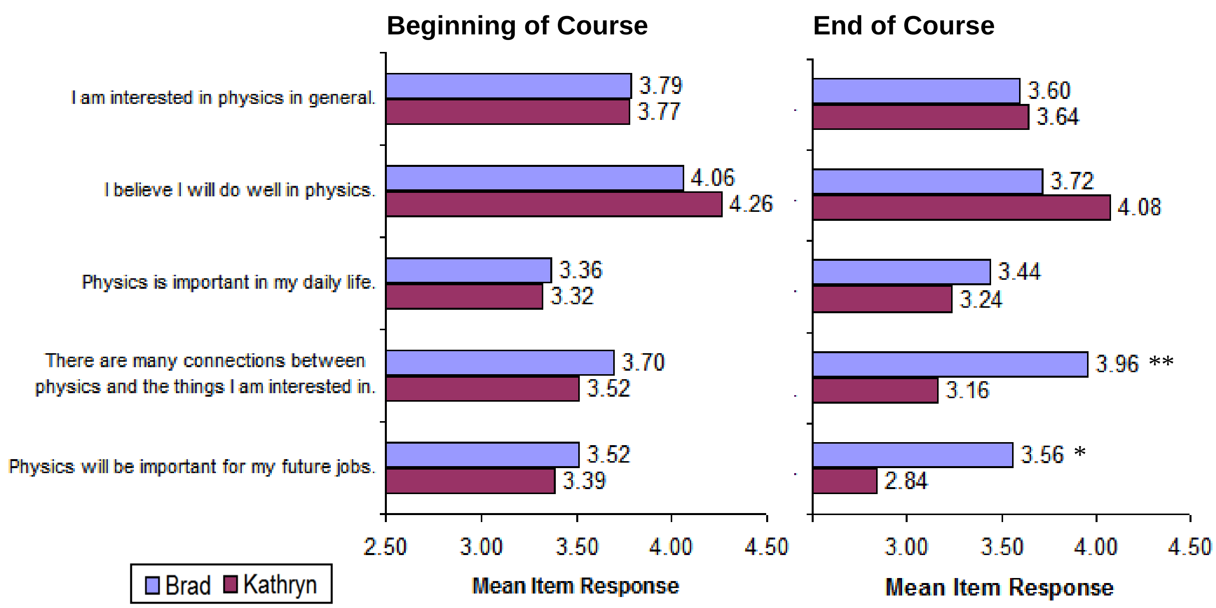
This last section examines the survey results of student attitudes toward physics from the beginning to the end of the course, so as to determine the impact of hybridization (through Text-Synergy) over time. This survey consists of 8 items that were repeatedly asked three times at the beginning, mid-term, and end of the course. Each item used a 5-point Likert Scale ranging from strongly disagree (1) to strongly agree (5). The same survey was also administrated to a non-intervention honors physics class taught by Kathryn as a control group. (The mid-term survey data for this class could not be collected.) The sample size and gender distribution of the students that took part in these surveys across the two classes are shown in Table 10.

Table 10. *Sample Size and Gender Distribution in both Honors Physics Classes*

		Brad's Class	**Kathryn's Class (Control Group)**
Beginning of course	Sample Size	33	31
	Male Students	22	9
	Female Students	11	22
End of course	Sample Size	25	25
	Male Students	16	5
	Female Students	9	20

The ratio of male to female students was almost opposite between the two classes – 2 : 1 ratio in Brad's class compared to a 1 : 2.4 in Kathryn's class. This composition was a result of the school's timetabling schedule. According to the school records, there is no significant difference in the first and second term examination scores between the two honors classes. Furthermore, both Brad and Kathryn were experienced teachers who had been teaching in Victoria High for more than nine years. Both of them also adopted a similar literacy approach toward teaching physics and they closely shared their teaching materials and approaches, including the use of the same textbook. Thus, the comparison between these two honors physics classes is a fairly valid one. The major exception in the two classes was the implementation of Text-Synergy in Brad's class.

At the beginning of the course, independent sample t-tests showed there was no significant difference between Brad's and Kathryn's classes in all 8 items in the survey. This ascertained that the students' attitudes toward physics between the two classes at the beginning were very similar. At the end of the course, this remained the case except for two items – (a) *connection* between physics and their personal interests and (b) importance for future *jobs*. For the connection item, the mean for Brad's class (M = 3.96, SD = 0.98) was significantly higher than Kathryn's (M = 3.16, SD = 1.10); t = 2.71, p = .009. For the future job item, the mean for Brad's class (M = 3.56, SD = 1.08) was also significantly higher than Kathryn's (M = 2.84, SD = 1.14); t = 2.29, p = .03. Figure 25 shows the mean item responses (5 = strongly agree) from five selected questions of the survey. As the graph shows, the means between Brad's and Kathryn's classes for every item were very close, except for the last two items – connection and jobs – at the end of the course.



* p<.05, ** p<.01. Variables are z-scores (mean=0, SD=1)

Figure 25. Comparison of student attitudes toward physics between both classes.

The significant change in the connection item at the end of the course amidst the other 6 items remaining unchanged is a critical finding that implies the isolated effect of Text-Synergy. That is, students found a stronger connection between physics and their personal interests as a result of Text-Synergy. (Later analysis will show that the effect was restricted to mostly female students.) Because the differences in the other 6 items remained significantly unchanged, it is reasonable to argue that the effect on the connection item was not significantly due to some other variables. For example, if the difference in teachers (e.g., personality, experience) had played a huge role in connecting the students' interests to physics, then the other items should also register a change, most notably the first two items on general interest and self-efficacy. But because no other significant change was found in any of the 6 items, I can conclude that the effect on Brad's students making a greater connection with physics was mainly due to the intervention of Text-Synergy. This interpretation is further supported by survey results and interviews that showed the major reason why students in Brad's class liked Text-Synergy and found it useful was due to the real-world connection it made to their interests outside the classroom.

As for the other item, job importance that also saw an increased difference, there was insufficient data to explain why this was so. One hypothesis may be that through the research required in Text-Synergy, the students learned that physics involved many more careers than they had initially expected. Based on the choice texts I collected, these careers might involve sports scientists, energy consultants and environmentalists, and electrical engineers.

Gender Differences in Attitudes

Going back to Figure 25, although there was a significantly increasing gap between Brad's and Kathryn's class in the connection item at the end of the course, there was actually no significant increase between Brad's beginning and end of the course (from M = 3.70 to M = 3.96). However, when gender difference is taken into consideration, the differences in this item became apparent, as shown in Figure 26.

When divided by gender, Figure 26 shows that the changes in the mean of the connection item were insignificant for male students in both classes. However, for female students, there was a steady increase in the mean of the connection item for Brad's class from M = 2.82 (SD = 1.25) at the beginning to M = 3.18 (SD = 1.08) in the middle to M = 3.56 (SD = 1.13) at the end of the course. On the other hand, there was a decrease in the mean for Kathryn's class. The graph also shows that while Brad's female students initially found less connection between physics and their interest areas compared to Kathryn’s class, by the end of the course, they had surpassed the female students in Kathryn’s class.

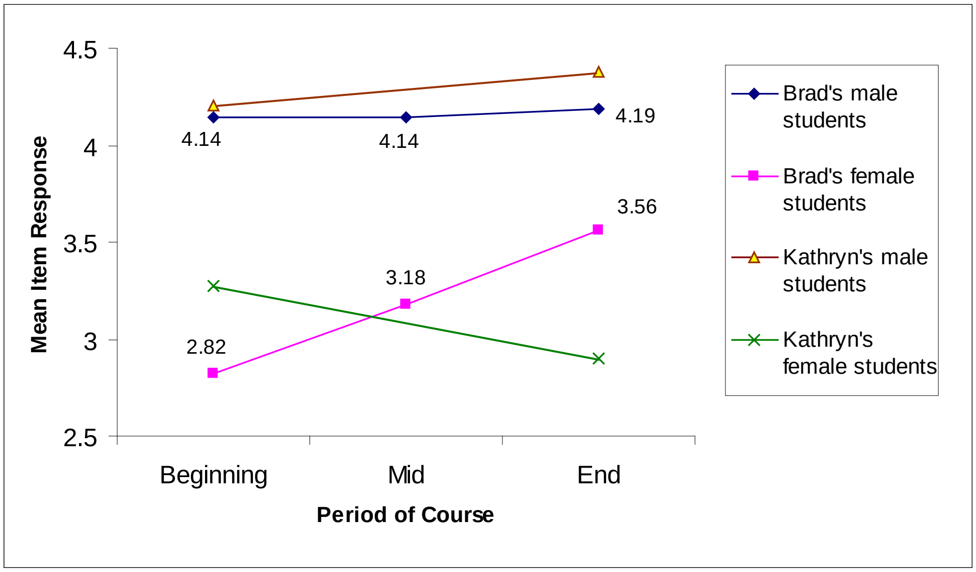


Figure 26. Changes in the mean of the connection item by classes and gender.

What is also important is that the gap between how Brad’s male and female students saw the connection to physics narrowed as the course progressed. At the beginning of the course, the mean for male student (M = 4.14, SD = 0.84) far exceeded the mean for female students (M = 2.82, SD = 1.25); t = 3.62 , p = .001. By the middle of the course, the difference narrowed but was still significant at t = 2.81; p = .008. By the end of the course, the mean for the male students (M = 4.19, SD = 0.79) was no longer significantly higher than the female students (M = 3.56, SD = 1.13); t = 1.60, p = .12. In other words, in terms of how the students related their interests to physics, the female students who started off feeling more disconnected at the beginning, had closed up the gap with their male counterparts such that the gap was no longer statistically significant. I will explain briefly why this was so.

Because the means for male students in both classes remained steady throughout the course, this suggests they already knew that physics played a significant role in their hobbies and interests before they entered the class. This is most likely because most of the male students' interests centering around automobile and popular sports (e.g., football, baseball) were commonly featured in science talk and documentaries. Therefore, they were not surprised about the connection when they searched and incorporated their choice texts into the lesson, and consequently the impact of Text-Synergy on their perceptions of how physics was personally related was minimal. This is corroborated by the fact that students who brought texts they had previously read or watched before (e.g., Sport Science videos, car magazines) were all males.

On the other hand, female students were generally less aware of the connection between physics and their interests prior to entering the class. From interviews and students' journals, when female students searched for a suitable text, many of them were pleasantly surprised to see how much physics was involved in their interests and hobbies. Evelyn, for instance, mentioned during the interview that she "didn't know physics is so involved in colorguard", where colorguard was often described as "her life." She also wrote that "it's cool to see how there's an exact science to what I do" in her journal. Therefore, it was not until they were required to search for a text in Text-Synergy that they realized the real-world connection between physics and their interest areas.

Furthermore, the results shown in Figure 26 also need to be interpreted in light of the findings from chapter 5 where I showed that the ideology of patriarchy in sports and physics discourses tends to marginalize female students. In Table 7 of that chapter, I showed how the examples given in their physics textbook overwhelmingly feature male-dominated sports like baseball, football, and ice hockey. Because the examples always portray sports that are generally played and enjoyed by men, this was a reason why many female students did not feel any strong connection to their sports, especially sports like gymnastics, cheerleading, and colorguard. This might even explain why there was a drop in the mean of the connection item for female students in Kathryn's class as the course progressed; that is, these female students increasingly saw that physics was mostly restricted to just balls and cars. Yet, despite this marginalization from the textbook, the female students in Brad's class could see an increased connection with physics as the course progressed. This, coupled with the earlier finding from Figure 25, strengthens the claim for the isolated effect of Text-Synergy in making a stronger real-world connection between physics and the female students' interests. The implications of this finding for gender equity in physics will be further discussed in the next chapter.

Summary: Hybridization in Fostering Critical Literacy and Narrowing Gender Gap

The first key finding in this chapter is the relationship between the discursive modes in the students' written explanation and their critical evaluation scores. Students who explained using a mixed discursive mode generally performed better in critically evaluating how science was represented differently across out-of-school texts and the physics textbook . This came about because the juxtaposition of multiple voices, identifications, and perspectives helped the students to discern and appreciate the necessity for various discursive moves in different texts, according to their different purpose, audience, and interest. Conversely, when a single voice was overly dominant, it hindered the students' consideration of a contrasting perspective to balance their critique of out-of-school or school-based texts.

This finding implies the merit of hybridization beyond helping students to construct conceptual knowledge across discourses (shown in chapter 6), to also fostering their critical literacy in evaluating how science is represented across discourses. The development of critical literacy has two major benefits for science teaching and learning. First, it is vital in an information era where adolescents are constantly exposed to all sorts of texts about science, with their various inaccuracies, "scientific-resemblance" claims, and socio-political voices. Thus, there is a need for students to gain some aspects of what Roberts (2007) calls Vision II of scientific literacy in understanding the role of science embedded within socio-political issues, instead of merely Vision I of its disciplinary aspect (e.g., knowledge, concepts). The second benefit of critical literacy is in getting students to appreciate the reason why scientific representations are made a certain way, instead of labeling them as "dry" and "boring." This could alleviate some of the students' negative attitudes toward school science and science.

In terms of student attitudes, the second key finding in this chapter is the increase in how female students in Brad's class perceived the connection between their personal interests and physics, relative to the male students and also the female students in Kathryn's class. As Text-Synergy progressed, female students in Brad's class responded in the survey an increasing perceived connection between physics and their personal interests, while female students in Kathryn's class responded otherwise. In light of the gender bias against female-dominated sports in physics examples as shown in chapter 5, this finding shows that the incorporation of students' texts and the hybridization requirement in Text-Synergy had an impact on how the female students saw a stronger real-world connection between physics and their interests.

The implications of these findings for classroom practice and research will be further discussed in the next and final chapter.

Chapter 8

Conclusion & Implications

Hybridizing Understandings Thesis

In sum, when two or more discourses about similar natural events were directly juxtaposed in a third space, conflicts were generated that potentially marginalize certain students. This was particularly so for students whose embedded experiences and social affiliations within certain discourse communities led to their preferred ways of looking at the natural world from one particular discourse, and consequently adopting a negative stance toward alternative ways in other discourses. However, through several instructional designs and supports, juxtaposition also made it possible for some students to hybridize multiple cultural understandings of the natural world. The mechanisms for them to do so entailed their being aware of heteroglossic differences across discourses, shifting their identifications toward the dialogic other, momentarily suppressing their preferred voices, and juxtaposing the other's voices for strategic motives. Not only was hybridization instrumental in facilitating these students' construction of conceptual knowledge across discourses, it also increased the opportunity for critical literacy in evaluating how science is represented across various discourses. This process of juxtaposing these multiple discourses leading to critical literacy is what I had called "hybridizing understandings" in this dissertation, and Multimedia Text-Synergy was a particular instructional design that created the conditions and setting for hybridizing understandings.

In this concluding chapter, I summarize the major findings from the previous four chapters to bolster my thesis of hybridizing understandings as outlined above. This is followed by a discussion of the contributions to and future directions for research, which will be divided according to the dual aims of design-based research: the improvement to learning theory and classroom practice.

Summary & Contributions of Findings

The purpose of this dissertation was to simultaneously forge and study a hybrid third space in a high school honors physics classroom. In tackling this daunting task, I had designed Multimedia Text-Synergy as a way to (a) initiate the opening up of the classroom space for multiple discourses to converge, interact, and hybridize, and (b) render these processes visible for study. In particular, the key to Text-Synergy was the use of the students' texts as entry points to interconnect their life trajectories to what they were about to learn in school physics. Through these entry points, an opening was also created for me to address both the critical ethnographic and curricular transformative research questions. For critical ethnography, the questions I raised were as follows; What was the nature of the students' texts and funds of knowledge in relation to mechanics and electricity (chapter 4)? What were the associated discourses and how did they interact with school physics discourse (chapter 5)? For curricular transformation; How did the students navigate around multiple discourses, and what was the role and process of hybridization (chapter 6)? How did hybridization manifest in the students' learning outcome through the enactment of Text-Synergy (chapter 7)?

Critical Ethnography Goal

The first step in my analysis was to draw connections between the students' selection of choice texts to their lifeworld experiences, activities, and literacy practices. This was the purpose of chapter 4, which used ethnographic methods to describe the rich diversity of the students' out-of-school readings and participations that had relevance to the topics of mechanics and electricity. This was essential in providing an empirical basis for knowing what kind of youth experiences and funds of knowledge were used as resources for learning physics, instead of relying on common assumptions about what today's youths knew and were interested in.

The findings from chapter 4 showed two intricate relationships among (i) texts, (ii) experiences, and (iii) social affiliations. The first relationship was the notion of text-experience reciprocity, which removes the prevalent dichotomy of texts and experiences, or "minds-on" and "hands-on" activities. This notion was instrumental in understanding that out-of-school participations cannot be attributed to *either* experiential activities (e.g., playing sports, going field trip) or media exposure (e.g., reading magazines, watching TV), but to *both* aspects in an interconnected and mutually supporting way across space and time. In this sense, although the methods of Text-Synergy had initially foregrounded the use of texts, what ensued for both my analysis and the connections made by the students were not entirely text-centric when the larger network of text-experiences was considered.

The second relationship connected the text-experience trajectory of individual students to their network of social affiliations with family, peers, local and distant communities, and popular media. These affiliations provided the cultural capital that shaped the students' habitus toward their out-of-school interests and activities. An essential finding was that students' habitus was not only tied to the activities they were doing or the content of the texts they were reading, but also to the social affiliations that sustained it; for example, with whom they watched TV, the number of friends involved in the sports, the friendship and family ties in church, and the affective-symbolic associations with pop icons.

By tracing these affiliations, I accounted for how voices were appropriated through the circulation of texts and people within a connected community spread over geographical spaces. This voice appropriation was important in explaining how students spoke from a particular discursive viewpoint associated with their community, which subsequently manifested as their attitudes toward certain aspects of life. This was most clearly seen in Naomi's case where her attitudes toward evolution and how it was taught were traced to her membership and social affiliations in church. The findings in chapter 4 therefore supported the case I made for this dissertation: it is not sufficient to investigate students' attitudes toward science without examining further how their attitudes were embedded in their experiences in and social affiliations to certain communities.

Based on the findings of chapter 4, I took a step further from individuals and communities to discourses in chapter 5. I explained that a discourse is a "city-level" view in looking at the patterns constituted by the trajectories of collective individuals within and across their communities, and is useful in examining the collective knowledge and dispositions of people and their voices. This allowed me to firstly distill five major discourses (sports, automobile, popular science, environment, creationism) based on my data, and, secondly, contrast them with school physics discourse. As such, it provided a more nuanced analysis compared to the dichotomous "everyday" versus "scientific" discourse prevalent in contemporary educational research.

The major finding in chapter 5 explained how each discourse could frame a different phenomenon from a common natural event, thus creating conflict between discourses when they were brought together in a classroom. I explained four different semiotic-technological systems that were responsible for the diverging phenomena: (i) the semantic system which labels and categorizes our experiences and perception of events; (ii) the spatial-temporal which shapes our indexing and quantification of our experiences within space and time; (iii) the visual which influences our "view" of events and reality; and (iv) intertextuality which brings together our history of text-experiences into juxtaposition with current text production or interpretation. I also provided two sets of phenomena involving the natural events of movement and the human body to illustrate how, despite the similar content, what was being construed in each discourse was actually different. For movement, sports and automobile discourses foregrounded the human and personal phenomena of generating, harnessing, appreciating, and evaluating the movement of athletes and cars, while school physics discourse stressed the impersonal, objectified, and universal forms of motion. For the human body, creationist discourse constructed a phenomenon that directly and personally implicated the reader's and author's relationship with a divine being, while school science framed a phenomenon of material interactions among inanimate lexical concepts such as neurons and charges.

This finding showed that learning physics involves more than just gaining content knowledge, but also learning the particular ways of framing and interpreting according to its semiotic-technological systems. Furthermore, for the group of students I observed, the contrast between the out-of-school and school physics discourses was found to be less in the presentational dimension (conceptual understanding), and more in the orientational dimension (stance and dispositions). Thus, students' immersion in one particular discourse not only influenced their preferred ways of looking at a natural event, but also their positive or negative stances toward other ways of looking at the same event from another discourse. The examples I gave included the use of affective photographs (often with music) in sports over abstract diagrams in physics, and the value of functional knowledge in automobile over formal and mathematical knowledge in physics. This accounted for why students' attitudes toward science were deeply rooted in the kind of discourses they were students' immersion in one particular discourse not only influenced their preferred ways of looking at a natural event, but also their positive or negative stances toward other ways of looking at the same event from another discourse exposed to. It also explained research studies that repeatedly found, despite the numerous overlapping content between physics and students' interests, an "apparent contradiction between students' attitudes toward science in general and their attitudes toward school science" (Osborne et al., 2003, p.1060). Consequently, when two discourses were juxtaposed because of their seemingly similar content, the underlying conflicts among the discourses could lead to the isolation, rejection, and marginalization of many youths. This was particularly the case for youths with discourses that are ideologically incompatible with or polarized from school science discourse (e.g., Naomi, Lucy, Evelyn).

Overall, under the critical ethnographic research dimension, it was found that a great learning opportunity was created through the opening of classroom space for multiple discourses. Due to the students' rich funds of knowledge, there was a diversity of topics, experiences, and media tapped as resources for learning mechanics and electricity. More importantly, the students themselves recognized these funds and brought texts with content similar to that of the physics syllabus. However, a deeper critical analysis revealed that making the connections involved much more than content similarity. It also involved the larger discourse and ideology that surround the way the content was framed. This is particularly important as most science teachers tend to only see and make an experiential or content connection to students' interests without being aware of the underlying discursive and ideological conflicts that might negatively affect the students' attitudes toward what they were learning. Consequently, forging a third space would require serious attention to this issue, and this was what the second research dimension – curricular transformation – aimed to address.

Curricular Transformation Goal

Under curricular transformation, the main goal was to understand the process and outcome of student learning as a result of Text-Synergy. The findings from chapter 5 raised questions as to how students could navigate across the gap from their various out-of-school discourses. This challenge was further heightened by Text-Synergy's requirement for the students to explain their choice texts "like a physicist" by using appropriate scientific terms and representations. To address this issue, I started by examining how several students managed or struggled in the explanation component of their text assignment, and through the analysis, I observed the most salient theme of this dissertation – hybridization.

As a way of understanding this under-studied phenomenon, I carried out a micro-genetic analysis to examine a critical conversation between Lucy and Evelyn and myself as the teacher-researcher as they discussed the physics principles involved in a colorguard toss. Through this analysis, four characteristics of hybridization were observed that enabled Lucy and Evelyn to navigate around the discourses of colorguard and school physics, and consequently fulfill the requirements of Text-Synergy's assignment.

The first characteristic is an awareness of heteroglossic differences in the use of language, while the second involves a shift in identification toward the dialogic other's way of talking and thinking. These were reflected in Lucy's sensitivity in using appropriate physics terms and her translations for the camera as the dialogic other, as well as Evelyn's reflection on the dialogic other's expected response, followed by her own self-question-and-answer. The third characteristic is a juxtaposition of multiple voices in order to synthesize knowledge from various perspectives, as seen in the frequent instances of hybrid utterances, and the corresponding back-and-forth movement of ideas across Lucy, Evelyn, and Kenneth. The last characteristic is the strategic and temporary suppression of preferences and identifications for short-term goals as shown by how the students devised strategies to deliberately privilege the dialogic other's voices over their own in order to get better grades.

These characteristics highlight the resourcefulness of some students in using hybridization as a strategic tool in remediating the discourse differences in a dynamic and situated manner. This suggests that sufficient credit should be given to the students' motivated interest in how and why they chose to hybridize at any particular moment for various reasons under various circumstances. It also led me to agree with Gee (2000) in characterizing these adolescents as shape-shifting portfolio people who are able to rearrange their skills and identifications dynamically and creatively under different circumstances, and are better suited to meet the demands of the new capitalist world.

With a better understanding of the mechanisms of hybridization, I went on to analyze in chapter 7 how hybridization was manifested in all the students' essays, and also to explore its relation with critical literacy. Statistical analysis showed that students who wrote using a mixed discursive mode in the first cycle generally performed better in terms of critical evaluation. This suggests the merit of hybridization in fostering critical literacy in evaluating how science/nature is represented across various discourses. This finding was further explained by the juxtaposition of multiple voices found in several exemplary essays. In other words, the multiple perspectives and identifications in the explanation helped these students appreciate the necessity for various discursive moves in different texts. They were also crucial in getting these students to strike a balance in critically evaluating the text's purpose and the way it was produced.

Finally, in terms of attitudinal changes, survey results showed an impact in how Text-Synergy changed the way female students saw the connection between physics and their personal interests. In particular, female students in Brad's class found an increased connection compared to the female students in a comparable non-intervention honors physics class who saw less of a connection. Furthermore, female students in Brad's class, who started off feeling more disconnected at the beginning, had caught up with their male counterparts as Text-Synergy progressed. This occurred because, in general, female students were less aware of these connections compared to male students who frequently saw their interests and hobbies (e.g., football, automobile) featured in science examples (part of a patriarchy ideology discussed in chapter 5). Thus, by requiring every individual student to relate his or her own interest to given physics topics in Text-Synergy, this particularly helped the female students make a stronger real-world connection to their personal interests.

Overall, the curricular transformation of Multimedia Text-Synergy was successfully implemented in the classroom, with desirable outcomes achieved by majority of the students. For hybridization and critical literacy, I can claim that the class on the whole (70%) performed well in critically evaluating their texts. Several students (e.g., Naomi, Lucy, Mike), through their multiple identifications, were also able to recognize why various discursive moves were necessary for different purposes and audience, and consequently hybridized by shifting their own preferred voices accordingly. However, I do not claim that every student could successfully navigate around the multiple discourses. In other words, hybridization was not observed for all students. Neither do I claim that every student had achieved critical literacy in terms of understanding and critiquing how different representations of science were made by various social groups according to their vested social-political interests. There is still some way to go before this Vision II of scientific literacy (Roberts, 2007) can be fully realized. Nonetheless, the primary goal of my dissertation was to gain an insight into the mechanism of hybridization and critical literacy rather than claim definitive success of my intervention, and in this aspect, I can conclude that my objective in terms of understanding hybridization's characteristics (chapter 6) and benefits (chapter 7) has been met. Through this insight, future research and implementations can realize the full potential of hybridization that I saw emerging in my study. This is where I will discuss the potential impact of my research for future directions in theory and practice.

Discussion & Future Directions for Theory & Research

I had argued that hybridization is one of the least understood phenomena in educational theory and research. The insight on hybridization gained from this dissertation will not only contribute to third space studies in education, but could also extend to the theory of learning in general. I start this discussion with a broader focus on learning before narrowing it to a specific focus on third space.

Hybridization as a Learning Mechanism

Most current theories of learning in all its variety (e.g., behaviorism, cognitivism, constructivism) have tended to focus on a "deficit model" where there is a certain shortfall in the mind or behavior of students that needs to be replaced or transited toward a superior form of stable knowledge or culture. Perhaps this deficit model may be valid for children as they are still developing bio-neurologically. (Not surprising, most of these theories were derived from studying young children, e.g., Piaget, Vygotsky.) However, the problem arises when the deficit model is extended to high school and college adolescents, particularly within academia when a "discipline" or subject matter is being taught. Under such a model, adolescents are seen as "underdeveloped" and thus have to be refined or educated. This tendency is further reinforced by an ideological assumption of positioning adolescents as "becoming" into adults through a transitional stage filled with problems and confusions (Lesko, 2001). This was most notably seen in Erikson's (1968) stages of psychosocial development, which marks the "adolescence" stage (age 12 to 19) as filled with "identity crisis" as well as radical change and anxiety accompanied by puberty. Such positioning of adolescents thus supports the logic of prevailing learning theories, and provides justification for educators to impose a one-way transmission of disciplinary knowledge and culture in their teaching.

Bhabha's notion of hybridity offers a new paradigm of looking at the issue. Beyond the stable binary of an "underdeveloped" mind *becoming* into a "developed" mind, or a savage discourse *transiting* into a disciplinary discourse, hybridity provides a dynamic view that diffuses the existing boundaries and categorizations, and highlights the resourcefulness of adolescents. In my analysis, this seems to be the mechanism employed by several students to navigate the chasm between discourses by shifting their identifications and preferences and juxtaposing voices in a situated, dynamic, and goal-oriented manner. This was particular striking in the affective dimension where they temporarily suppressed their preferred stances (e.g., humanist, free-style, creationist) to accommodate those in science (e.g., reductionist, factual, secular) in exchange for certain short-term incentives. Thus, instead of characterizing these youths as having multiple "identity crisis" as popularized by Erikson (1968), I saw instead a fluid and strategic shift of identifications, or "shape-shifting" in Gee's (2004) term.

Through this observation, I began to see how hybridization, through the back-and-forth shifting of one's identifications and voices between discourses for strategic purpose, could be an important but unexplored mechanism of learning at a later age. This offers an alternative perspective to the one-sided dichotomous view where learning is the exchange or transition from one stable form to another. Furthermore, unlike current cognitivist and constructivist theories, hybridization also accounts for the strategic and functional motives of adolescents and adults in their learning within a political and social structure. As such, it gives a more realistic view of learning that is intricately tied to the exchange of socio-economic goods. Examples of such distinctions between hybridization and other constructivist theories of learning, and their relative strengths and limitations were discussed in chapter 6.

I am not suggesting that current learning theories are wrong and have to be replaced. Instead, these theories can be particularly useful for certain research and educational purposes. What I am arguing is that hybridization can provide another lens for interpreting and understanding how people bridge those differences – not as an either-or binary but as a dynamic and fluid in-between. Hence, instead of challenging old theories, my aim is to point at a new area for future research in order to shed light on this important but ill-understood process of learning. Future research could also look into how the theories of Bakhtin's hybridization, Vygotsky's scaffolding and ZPD, and Piaget's cognitive dissonance can be used in complementary ways to enhance our understanding of the complexity of learning.

Contributions to Third Space Theory & Research

In terms of the contribution to third space research, I had argued that part of this dissertation was to fill a gap on educational research of third space, particularly in high school science (Moje, 2007). The successful implementation of Text-Synergy contributes to this work just by being a testimony that a third space in high school physics is both possible and desirable. However, a greater contribution is also the finding of “hybridizing understandings” that sheds light on what exactly is a third space and its contribution to education.

Although the idea of a third space is gaining currency in educational research, much is still not understood about what a third space comprises and its value for learning. In science education, there is also a concern whether the kind of science promoted in a third space could be considered a legitimate and valuable form of knowledge. My findings present an alternative view of a third space that has rarely been heard; that is, critical literacy could be a desirable result of hybridizing understandings. By juxtaposing multiple discourses about similar natural events, I showed that not only was there no adulteration in students’ conceptual understanding of science, there was also potential in promoting a critical literacy where students were able to critique different representations of science made by various social groups. As such, critical literacy should be a major component of third space and a rationale for educational research and practice. The practical benefits of a critical literacy will be further discussed in a later section.

In terms of researching third space, Text-Synergy utilized a different methodological approach based on a Latourian socio-technical network of mobile elements (e.g., people, texts) circulating in space-time instead of an overlap of two abstract containers (see chapter 3). Instead of the researcher or teacher looking for the home-school connection, the students themselves were empowered to look for their connections right from the beginning of a lesson unit. After each student had identified his or her own connection with the unit to be studied, then the researcher conducted his ethnographic investigation to find out more about this particular connection. Such an approach reversed the predominant direction in third space research; instead of looking for a union before the intersection by the researchers, the intersection was made by the students themselves at the beginning, and then the researcher branched out from that intersection to connect the in- and out-of-school discourses through a network trajectory.

This approach had several pedagogical and research benefits. First, the empowerment of the students to actively seek their connections helped them find a closer connection between physics and their personal life. It also brought a greater sense of ownership to their learning process when they found something close to their passions and interests. Second, as the students were the ones who looked for the connection from their point of view, this helped the researcher identify how they saw and recognized the content similarities across disparate discourses. This provided the opportunity to investigate how discourses could differ even when they were dealing with similar content. Lastly, getting the students themselves to make these connections was also a prerequisite step in fostering critical literacy as shown from the analysis in chapter 7.

Overall, the findings and approach of this dissertation builds on earlier work that pioneered a new paradigm of addressing educational equity by foregrounding students' home resources. As the field is relatively new, studies in third space thus far were limited to the focus on students from diverse ethnic groups and low-income families, and glossed over the specificity of how out-of-school discourses could create diverging phenomena and conflicts with school-based discourse, or "official scripts" (Gutierrez, et al., 1999). By applying in new settings and using a discursive lens, I was able to push this emerging field further by providing a level of detail and nuances to show exactly how conflicts arise from the intersection of discourses as well as the mechanisms of hybridization to help students become hybrid creators.

Finally, it is necessary to point out that the major difference between my work and earlier third space studies was predicated on different demographic sampling. While most studies have focused on students from non-dominant backgrounds, my sampling was based on a honors physics class from a more privilege background. Therefore, the expectations from these students (and the criteria for evaluating this study) are quite different. Yet, this also illustrates how much work has not been carried out on mainstream students, and how much new insights could be gained by exploring this uncharted territory. In addition, I have shown that power relations and discrimination were not exclusive to students from non-dominant backgrounds (which is the main motivation of current third space work), but was also evident in mainstream honors classes where most educators would presume are devoid of power struggles and negotiation.

Although I did not foreground the issue of power in my analysis, this was implicit in many of the examples I have provided. As I briefly discussed in chapter 5, the denial of cheerleading and colorguard as official sports greatly shaped how several students (e.g., Lucy, Melanie) talked about their sports, which surfaced in their classroom dialogue and essay writings. In Naomi's case, the negotiation of her identification straddled between two powerful discourses – science and religion. Arguably, these power relations played a huge role in her motivation to be an "A" student, a doctor, and a good Christian at different times of her life.

In the enactment of Text-Synergy, I had also not analyzed the role of power that Brad and I had over the process of hybridization negotiated by the students. Therefore, there is much scope for future research to explore this issue and learn about the nature of these power relations and how they play out in the life of all adolescents, not just those from the "traditional" marginalized groups (e.g., ethnic minorities, low-income families).

Discussion & Future Directions of Text-Synergy as Classroom Practice

Contributions to Classroom Practice

Realizing the huge gap between home and school discourses, many educators have taken up the challenge to connect students' interests and knowledge with school-based curriculum (e.g., Mortimer and Scott, 2003, Wells, 1999). Focusing on the bridging or scaffolding required in helping students connect their home discourse to the specialized discourse of science, many studies have shed light on the important experiential and cognitive processes involved in making the connection. As I made the case in chapter 5, making the connection involved not just in terms of the content similarity, but also the ideological ways of framing and interpreting according to different semiotic-technological systems of each discourse. Thus, it is equally important to consider the multiple literacies, stances, dispositions, and identifications that students had to navigate across the discourses in addition to the experiential/cognitive connection. Furthermore, I also showed that the contrast between the discourses was not between a binary of scientific and an all-encompassing "everyday" discourse, but really involved multiple secondary discourses that students gained through their diverse participations and social affiliations across multiple communities.

Therefore, to effectively bridge or scaffold students' learning toward science discourse, besides the connection in terms of content, educators must also think of ways to explicitly help students address critically the differences in the language, symbolic systems, and ideologies of the various intersecting discourses. In this respect, Text-Synergy provided a viable and practical approach to address such contrast in discourses by getting students to directly compare their familiar texts about science, nature, and technology with those they learned in the classroom. Through such comparison and a hybridization of voices, I showed that many learning benefits could be derived.

The first benefit was that Text-Synergy provided the basis for some students to construct conceptual knowledge by dynamically shifting their voices and identifications in navigating the gap across discourses. This was most clearly seen in Evelyn, who started off as a under-performing student with a low interest in school physics. Secondly, it made some students appreciate the necessity for scientific representation to be "dry", but straightforward and precise compared to the more colorful representations they were more familiar with and attuned to. This was seen in several of the students' critical evaluation as they compared their out-of-school texts with the physics textbook.

Thirdly, Text-Synergy also created the potential to foster critical literacy in evaluating how science is represented across discourses according to varying socio-political interests. Based on several examples in chapter 7, I showed the value of having an alternative representational perspective from out-of-school discourses, instead of over-emphasizing students to read and write scientific texts exclusively in science classrooms. This is because, without the juxtaposition of two different voices for comparison, it was difficult for students to critically evaluate the nature of scientific texts, and how and why they were made. Critical literacy is vital for a functioning democracy in an information era where all sorts of text are easily produced and accessible to anyone in a public forum. Many of these texts would include multiple and competing voices about the role and use of science and technology in society. There is thus an urgent need for students to discern these multiple voices, for example, the simplifications, biases, and exaggerations of science as represented in commercial shows and websites, or the claims made by various activist groups on issues like the environment, climate change, renewable energy, stem cell research, and evolution.

Lastly, chapter 7 also shows the learning benefits for under-represented female students through the implementation of Text-Synergy. The underrepresentation of women in physics has been a long-standing educational problem despite efforts in the last half century to recruit and encourage more women to study physics. While I do not claim that the approach of Text-Synergy had and could singlehandedly solve this complex issue, there are valuable lessons gleaned from my findings. First, despite efforts to change the image that physics is meant for boys only, the examples used to illustrate physics principles often inevitably reinforce that image. This was clearly seen in the number of examples featuring male-dominated sports compared to the nonexistence of cheerleading and colorguard examples (see chapter 5). Therefore, in making a real-world connection to the students' interests, educators need to know what students' diverse interests are, instead of making the connection based on common examples used over the years, most notably baseball and football.

Making a more conscious connection to female students' personal interests had an impact on how they perceived the connection with physics. This was shown by the sharp increase in the survey response over the course of the program in comparison to the decline for the female students in a non-intervention class. According to a large-scale survey study by Hazari, Sonnert, Sadler, and Shanahan (2010), the real-world/contextual connections were one of the main predicators for female students’ career choice in physics. Surprisingly, several experiences thought to be important for females' physics identity, such as having female scientist guest speakers, discussion of women scientists' work, and frequency of group work, were found to be non-significant. Therefore, the approach taken in Text-Synergy to get every student make a connection between his/her personal interest to physics could lessen the under-representation felt by female students, and thus offer a potential means to address the gender gap in physics.

Current Limitations & Future Iterations of Text-Synergy

Beyond this particular implementation of Text-Synergy in Victoria High School, eventually I envision Text-Synergy to be a viable model of hybrid third space for widespread classroom practice. In this section, I discuss current limitations of Text-Synergy as a classroom model and discuss its potential future iterations.

Youth demographics.

To assist future studies in implementing Text-Synergy in other demographics, it is necessary to discuss the characteristic traits of the youths in this study and whether those traits could be found elsewhere. Based on chapter 4, I would characterize two general traits about the youths that I have studied: activity-rich and media-rich. In terms of activity, many of the students were actively involved in multiple activities, particularly in sports and recreation. As it turned out, sports was the major component that engaged many students in drawing the connection between their interests and physics. As for media, the access to the Internet and Web 2.0 was another main contributor that facilitated the possibility of Text-Synergy. It would be difficult to imagine how Text-Synergy could be feasible 15 years ago when school-based research basically meant going to the library to physically browse for books and encyclopedia. Arguably, these activity- and media- rich traits were related to these students' privileged background of well-to-do suburban families, and it therefore raises the question of whether youths from less privileged backgrounds in other communities have the same kind of access.

Several research studies from the literature suggest that the rich connection between youth funds of knowledge and physics can also be found in many settings around the world; for example, an economically challenged district in California (Brown & Kloser, 2009), a low-income ethnically-diverse urban community in Michigan (Moje, 2007), and a remote village in India (Sharma, 2008). Although there will always be cultural and regional differences, one would find in any demographics potential in making the connection between students' funds of knowledge and school physics, provided that one researches with an open mind about what can be considered as funds of knowledge and not be restricted by institutional categories of knowledge. As such, there is much scope for research in this urgently needed area to find out more about what youths in other places are reading and experiencing in their out-of-school activities, and how these can be connected to school-based science learning.

Teacher's expertise & views of literacy.

As discussed in chapter 3, the selection of an effective teacher who was interested in a third space was based largely on Barton and Tan's (2009) recommendation of the teacher's willingness as the key factor. For an initial study that focused more on student funds of knowledge and the hybridization process rather than the teacher, this selection was justifiable. Furthermore, as the focus was on the students, the role and expertise of the teacher were not foregrounded in this study. However, if Text-Synergy is to be widely expanded, then the focus on teacher's beliefs and expertise will become an important issue for future research.

For future iterations of Text-Synergy, the teacher's epistemological views of literacy and disciplinary knowledge will play a key role. After several more iterations, the next logical step is also to address the issue of teacher preparation and training in order to scale up and sustain an approach like Text-Synergy. Such a preparation will have to, first and foremost, address teachers' epistemological view of what science is, how it should be taught, and the importance of critical literacy for Vision II of scientific literacy. It should also prepare potential teachers to integrate student texts into the curriculum, discuss the various representations of science by various social groups, and support students in their writing and evaluation in their essays. Each of these aspects can be considered a full study of its own, and needless to say, much more work and a lot of time will be needed in this area. In the next sub-section, I will discuss some of the things I learned with regard to the above-mentioned aspects, and offer suggestions for modifying several components for future classroom implementation.

Modified iterations & suggestions.

Future iterations of Text-Synergy need not follow exactly the steps and procedures I used in this study (as outlined in chapter 3). There is flexibility in adapting Text-Synergy for different student and curricular needs while keeping with the broad principles of incorporating and hybridizing student discourses. In this section, I outline a few possible alternatives that could achieve a similar goal to some extent.

In my study, every student was required to look for an individual choice text and submit an individual assignment. This had many advantages for both research and pedagogical purposes. However, I recognize that this can pose a lot of challenges for a teacher to address a diverse array of topics brought into the classroom and grading every assignment that is topically unique. One simple alternative in reducing this challenge is to turn it into a group work. This will not only make it more manageable for the teacher, but it can also foster collaborative learning among the students. Another alternative is to allow students the option of choosing from a pre-selected list of suitable texts of diverse topics. This alternative is possible after a few initial implementations to collect a repository of choice texts that could be representative of the region's youth population. Although this alternative restricts the diversity of students' personal choice, there is a trade-off in adding some predictability and control for the teacher, so that he or she can design lessons that can better integrate these pre-selected texts. The teacher can also ensure that the choice text selected will be suitable for the assignment, both for the explanation and evaluation. Moreover, it also allows a group of teachers to collaborate in sharing common resources, thus reducing the workload of individual teachers, especially in subsequent iterations.

Finally, Text-Synergy is certainly applicable beyond physics to other sciences, although much ethnographic research will be needed to first explore these uncharted territories. Through my interviews, I came across so many examples from the students that could be used in Biology, Chemistry, Earth Science, and Astronomy; for example popular TV series like *CSI*, *ER*, and *Bones*, science documentaries like *NOVA*, *Planet Earth*, the *History Channel*, and numerous sci-fi books and movies. In Biology and Earth Science for instance, Naomi's example also provided a compelling case to examine how many students felt marginalized or turned away from the discipline because of their faith. Therefore, through more systematic research, we can learn a lot more about the student funds of knowledge in this area, and how they can be used to support their science learning in a more engaging and critical way.

Institutional challenges.

Creating a hybrid third space like Text-Synergy is not going to be an easy task, and given the constraint of limited resources, there will inevitably be competing voices challenging its goal and implementation. As such, I want to highlight a few broad issues for a constructive dialogue about the purpose and merits of science education. The first issue is the willingness among science educators to open up and expand official school and curricular boundaries for students to bring their out-of-school texts on science-related matters to the classroom. As my findings have shown, these texts should not be brushed aside as inaccurate misrepresentations of science that distract or confuse students about the learning of "real science." Instead, by recruiting these texts for comparison and critique in Text-Synergy, the goal of scientific literacy in both Vision I and II (Roberts,

2007) can be further strengthened. In any case, most adolescents spend the majority of their time encountering texts in their interest areas more than academic science texts, which they will only see for a short period of time and a limited duration in their lifetime. For that reason, science teachers should channel some classroom time to discuss the contrast between school science and their out-of-school texts.

Another issue is the trade-off for classroom time and curriculum content. This is particularly challenging given the enormous amount of knowledge created in modern science, and the widespread belief (tied with political interests) that these need to be transmitted to as many students as possible, even when only a handful of them will eventually become scientists. I am not arguing that science is not an important discipline for every student to learn. Instead, I am raising the question of the extent to which each specific theory, concept, and formula needs to be taught to every student. Thus, there has to be some prioritizing of what specific knowledge is relevant and important for a well-informed citizen to participate responsibly in society, so that some of the more exclusive content and skills required for scientific and technical training can be postponed to tertiary education. This postponement should not be seen as a watering down of a rigorous science curriculum because what is being exchanged is arguably more relevant in terms of the students' needs, the changing literacy conditions in the digital age, and a balanced and critical literacy necessary for scientific citizenry. In this sense, Text-Synergy provides the basis for a reconceptualization of scientific literacy from one that focuses on "a narrow homogeneous body of knowledge, skills, and dispositions" (Linder, Östman, & Wickman, 2007, p.7) to one that stresses critical literacy on the multiple and conflicting perspectives of science.

Reflection: Hybridization of Educational Research

As the topic of this dissertation is about hybridization, it is itself a hybridized work spanning across multi-disciplinary approaches such as science education, literacy, linguistics, semiotics, anthropology, and the learning sciences. As I argue for the merit of hybridization in fostering new "in-between" literacy and knowledge for the adolescents I observed, the same could be said about the research communities in which I am embedded. In other words, I see this dissertation as a third space where multiple theories and methodologies "talked" to one another, and through the process, new interpretations and insights on educational issues were derived.

Such hybridization is important for the progress of educational research, often hindered by the numerous "culture wars" waged among competing epistemological and ideological camps (e.g. quantitative vs. qualitative., positivism vs. postmodernism, literacy vs. science education, ethnography vs. experimental research). We need to foster more dialogue, border crossing, and hybridization among these multi-perspectival voices for the benefit of the children and adolescents that we teach. In some ways, we can all learn from Naomi. a 15-year-old adolescent, who despite between sandwiched by years of historical power struggle among two dominant groups, was able carve a unique path away from the baggage of her predecessors into one where she could position herself strategically in an increasingly pluralistic and hybridized world.

Appendix A: Brief Biographies of Student Informants

Lucy (senior). Lucy was a veteran in the school colorguard team. She spent a lot of time in colorguard practice and described her friends there as “her family”. When she was younger, her family and a few neighbors used to do “crazy” science experiments and inventions and she recalled learning a lot of science from these activities. Although Lucy still liked science because of those childhood memories, her experience with a bad science teacher some years ago turned her off from science. During class, she took on a functional and information-driven approach in learning physics by selectively reading the most important information in her textbook. Besides colorguard, Lucy loved art, reading, and creative writing. At the time of research, she was admitted to a state university in arts and humanities and she planned to major in creative writing. She aspired to be a travel writer in the future. Lucy was one of the most vocal students in class and during interviews.

Evelyn (junior). Evelyn was also in the school colorguard team, and as such was very close to Lucy. Together with Margaret, a senior also in colorguard, these three girls formed a close clique in class. Incidentally, she had the same choice text of a colorguard video with Lucy. Evelyn was a later addition to my sampling, and was selected because I wanted to have at least two different students with the same interest for comparison purpose. Evelyn was also interested about environmental issues ever since her visit to her aunt’s energy-saving home in California three years ago. Among my informants, Evelyn struggled the most with physics and this was the main reason why she had a lack of interest on the subject. Evelyn chose to do honors physics because she thought that her abilities in mathematics would help her do well in the course.

Naomi (sophomore). Naomi had been a cheerleader for three years and was a flyer in the school cheerleading team. At home, she described herself as the “little nerd in her family” because of her passions in watching science documentaries and “spilling out random weird facts all the time.” She loved science, particularly biology, and aspired to be a cardiothoracic surgeon. For these reasons, she was among the most diligent students in class and she had an A for all her science classes, including honors physics. Naomi grew up in a Christian family and before the start of the second cycle, attended a creation class in her church. Thus, her second choice text was influenced by her participation in the creation class. Naomi had a bubbly personality and she enjoyed talking with Brad and I after school. She disliked English and writing.

Sabrina (junior). Sabrina had been playing soccer since she was 4 years old following her older brother. Besides soccer, Sabrina also enjoyed watching “court drama” like CSI, NCIS, and Law and Order with her family, whom she described was obsessed with these shows. Her dream career was to be a lawyer and that was partly why she loved to watch those shows. Shannon was an avid user of new media. She used the Internet extensively for social networking and communication, and also for general reading, which she enjoyed learning about “random things” whenever she was bored. She also maintained a personal website for recruitment purpose of promoting her passions and abilities in soccer for potential coaches.

Hank (sophomore). Hank had many interests and hobbies such as boating, fishing, golf, and skiing. He was also a car enthusiast who read and collected various car magazines regularly since he was in fifth grade. What he enjoyed reading the most from car magazines was the news and updates about cars and the advancements in the automobile industry. Although he read about the engine and performance aspects of the car, he admitted that he could not fully understand all of it. However, he found it useful to read the technicality aspect and taught himself some of it as he read along. In relation to physics, he could see how reading car magazines help him understand and appreciate physics more.

Benjamin (junior). Benjamin played for the school football and baseball teams. He was a quarterback in football and he pitched in center field for baseball. He watched sports programs on television very often, and he particularly enjoyed shows that explain the science behind sports, such as Sports Science, which provided his choice text in the first cycle. Benjamin's family owned an assembly plant that supplied automobile parts to Chevrolet. He regularly went to the plant to take up certain jobs and repairs, which his father had taught him. Benjamin wanted to pursue engineering in college as his aspiration was to take over his parents' company when they retired.

Zac (junior). Zac was into BMX and at the time of research, was ranked number 27 for his class of BMX riders in the nation. He started doing BMX racing when he was eight years old. His father often helped him tweak his bike regularly to get better performance during racing. Like Hank, Zac found his experiences in BMX useful in many ways as he connected what he learned in mechanics to his riding experiences. At home, Zac had a Play Station 3 and enjoyed playing videogames in his spare time. He planned to study mathematics or science in college.

Joe (sophomore). Joe played football for the school team as a linebacker. Like Benjamin, he watched sports channel on the television regularly and had a video from Sports Science (a different episode) as his choice text. He also read sports magazines every once a fortnight. In class, Joe interacted much with the football players, including Benjamin and two other boys. He was often close friends with Naomi and Hank. Joe planned to study engineering in college.

Appendix B: List of Chapters in Physics Textbook (Zitzewitz et al., 2005)

Legend:
** : chapter covered in the course*
+ : chapter partially covered in the course

Chapter 1 – A Physics Tookit*

Mechanics

Chapter 2 – Representing Motion*

Chapter 3 – Accelerated Motion*

Chapter 4 – Forces in One Dimension*

Chapter 5 – Forces in Two Dimensions*

Chapter 6 – Motion in Two Dimensions*

Chapter 7 – Gravitation+

Chapter 8 – Rotation Motion

Chapter 9 – Momentum and its Conservation*

Chapter 10 – Energy, Work, and Simple Machines+

Chapter 11 – Energy and its Conservation*

States of Matter

Chapter 12 – Thermal Energy

Chapter 13 – States of Matter

Waves and Light

Electricity and Magnetism

Modern Physics

Appendix C: Student Interview Protocol

Pre-Cycle Interview

Questions of Interest and Literacy Practices

1. Tell me more about your interest/text? What do you do in or read about the activity?

2. What spark off this interest?

3. How often do you engage in this activity? How long have you being doing it? What do you like about it?

4. How often do you read/watch this particular text? How long have you being doing it? What do you like about it?

5. What do you hope to learn when you read/watch this particular text?

6. Do you read a book or magazine or watch a TV program that is related to your interest? How often?

7. How often do you talk with your friends about your interest? What do you talk about?

8. Who produced this text? How do you know?

Specific Questions of Text

[Have a student read/watch various certain segments/passages]

1. What were you thinking when you first watched this segment / read this passage?

2. What do you understand by the word _______ here?

3. What do you understand by this sentence here?

4. Can you explain this passage/segment to me?

5. Is there anything in this passage that you don't quite sure about? How would you try to do to help you understand it better?

General Questions

1. What is your impression of this class so far?

2. Do you have any difficulty in understanding what you have been taught so far?

Post-Cycle Interview

1. How well do you think you have done for this assignment?

2. Go through with me the process of how you write this paper.
   i. How do you decide what to include in the paper?
   ii. How long did you take to do this assignment?
   iii. Was it easy/difficult? Which part is easy/difficult?

3. What do you think is the purpose of this text assignment that we ask you to do? Do you think this is important?

4. Did you look at the assessment rubric and exemplar when you write the paper? Why/why not?

5. Did you refer to your textbook when you write the paper? What did you look at? Why?

6. Are you a good writer? Do you like writing?
   i. Was it hard to write this 2-page science paper?
   ii. Does your ability in writing affects how well you do in this assignment?

7. Overall, how do you feel about this text assignment?
   i. Did you like this assignment? Bringing a text vs. writing a 2 page essay?
   ii. Does it take you a lot of time?
   iii. Does this help you to learn physics, and more motivated to learn physics?
   iv. What about the assignment where we want you to write a 2 page essay? How do you feel about this assignment? What are you going to write for your assignment?

8. Other specific questions based on what they have written in their papers.

Appendix D: Teacher Interview Protocol

Beginning-of-Term Interview

1. How would you characterize your teaching philosophy and approach?

2. What teaching strategies do you use?
   i. How do you go about teaching the content?
   ii. What kind of homework do you give? Do you grade all of them?
   iii. How would you compare yourself with other physics teachers in your teaching approach?

3. Tell me more about the use of a reading guide?
   i. Where did you get this idea from?
   ii. Why did you want to use it?
   iii. How effective has it been?
   iv. How do you prepare the questions?

4. What is the assessment criteria?

5. How do you envision this research would add/change what you have been doing? What do you hope to get from it?

Mid-Term Interview

1. How would you characterize the major changes in your teaching for this class compared other previous Honors Physics classes you have taught? What differences do you notice from the students as a result of these changes?

2. How useful do you think the text assignment piece is to: (i) the students, and (ii) your own teaching practices?

3. What are some challenges you face in implementing the text assignment?
   i. What could have helped you to do better?
   ii. What might you have done differently if there is no barriers?

4. What is your response to the survey results?

5. How would you integrate students' texts differently in the next term?

End-of-Term Interview

1. Can you think back before the project started, what were some of your initial thoughts or concerns about this project, and compared what you have gone through now, on hindsight, how has things changed?
    - i. What has been the most difficult part?
    - ii. Which is most rewarding?
    - iii. Were you comfortable talking about the diverse topics selected by the students?

2. How do you see the connection between Text-Synergy and the goal of getting the students to be able to read their textbook effectively?

3. Do you feel any difference of this class compared to previous cohorts in terms of:
    - i. Test scores and exam grades?
    - ii. Motivational/attitudinal?
    - iii. Information extraction and synthesis?
    - iv. Critical thinking and literacy?
    - v. Classroom conversation/discourse?
    - vi. Others?

4. If you try these with your new cohort, how would you do it differently in future?

Appendix E: Full Colorguard Text from Simmons, 2010

Colorguard Rifle Tosses

By Fran Simmons, Colorguard Floors

This article discusses basic rifle tosses, from single to quad. It assumes that the reader has had at least a little instruction in tossing a rifle, knows the parts of the rifle, and understands the positions of left flat and right flat. *This article does not claim to cover every nuance of tossing, or describe the "only" or "right" way to do rifle tosses.*

Getting started

Stand in a stable position. I like second position "boxed out" for practice. Feet are apart, shoulder width.

Start with the rifle at left flat. The left arm is bent, elbow *free* of but *in line* with the ribcage, with the left pinkie barely to the left of the bolt. I like to let the thumb ride along the very bottom edge of the barrel but it is tucked down, not extended. Keep the gun in your fingers, not in the palm of
your hand. This reduces twisting on the release. The right elbow is 6-8" out, in line with the body, forearm straight. The right hand rests lightly at the very end of the gun with no fingers overlapping. Keep elbows higher than wrists.

Stand with shoulders back, stomach in, feet shoulder width and legs turned out. Relax from head to toe; nothing twisted or tilted. Have enough tension in your shoulders, back and arms to keep someone from taking your rifle away. Check again when it's time to boost (aka dip - I don't
like "dip" because it implies lowering the hands and neither hand should drop).

The boost

My groups don't boost for a single. But for doubles and up:

Raise the right hand to shoulder height. Separate your shoulders. Don't grip the bottom hand too tightly.

Don't dig your elbow into your ribs. That can ruin arm path, slow down rotations, and, if you do it on the catch, it's Very Ugly because your body will contort around the rifle.

When you are set, look down at the rifle and make sure that your hands are in a straight line, and that the rifle is not rotated toward or away from you. Usually the culprit is too much tension in your fingers. Any line on the floor can be used to check your position. This helps improve pitch.

Break it down

There are four parts to a toss: push, lift, release, catch.

1. The **push** controls the rotations. I like to use the tips of my fingers to drag down the butt of the rifle like I'm slamming a door, but straight down, lined up with my elbow. Don't lean or bend your body forward or back during the push. Don't push the butt forward here or your toss won't be flat to the front (a.k.a. bad "pitch"). The push happens half a count before the release… e.g. "five six seven eight AND one", where you let go on one at the release point. You can subdivide this (as in the exercises to the right) using the word "re- LEASE", with the emphasis on LEASE because that's when the hand opens.

2. The **lift** raises the gun to the level where you're going to let go of it. Squeeze the left hand as the rifle is pushed down and transfer the energy from the swinging of the butt to the barrel. As you lift straight up, turn the left wrist like you are twisting a doorknob and lift straight up in line with your shoulder. I call this "**the channel**", an oval that goes up from your elbow straight up in a line that reaches higher than your head. If you do it right, your left elbow will follow your wrist straight up and not swing out as you toss. Again, keep the gun in your fingers.

Hot tip: *To work on the push and lift separately, do "fakes": push and lift to that release point but don't toss.*

3. **Release** at shoulder for single, at chin for double, eyeball for triple, and barely overhead for quad. I tell my kids that the release point is not negotiable – we all have to let go at the same place if we want the tosses to be the same height. The biggest rookie mistake is to do an extra push or twirl at the release point. Don't! Just open your hand there. Release straight up from your shoulder/ elbow line – don't "rainbow over". If your rifle is flying to the left, right or forward, it's because that is where you opened your hand. This *point of release* can be altered for your direction of travel… if you are moving to the right, release to the right, and the rifle will travel to the right with you. P.S. Don't jump!

In between release and catch, have a free hand position.

4. The **catch** for a basic toss is at right flat, hands at the grip and tip, wrists below elbows. Wait at your free hand position until the very last moment to catch the rifle. When you catch, act like you are pulling the rifle apart and box out. This helps control the line of the catch, and it looks impressive. Releasing on *and one*, I catch a single on *two*, a double on *two and*, a triple on *three*, and a quad on *three and* (or catch on four if you're just starting to throw quads).

<u>Exercises:</u> These are some exercises for Rifle Tosses.

- The word "release" is used to help subdivide the count
- My groups say the words exactly as written below.
- We say "hit" instead of boost… use what works for you.

Sgl:	Spin, spin, stop, wait, Re – LEASE! & 2 (hold, push 8)
Dbl:	Spin, spin, stop, hit, Re – LEASE! & 2 AND
Triple:	Spin, spin, stop, hit, Re – LEASE! & 2 & 3
Quad:	Spin, spin, stop, hit, Re – LEASE! & 2 & 3 AND!

Catch on either the count or half count (but don't stop counting). Push on 8 to restart the exercise (at spin, spin). For singles and doubles, you can count 1-8 continuously. For triples and quads, count 5678 in between for a breather. If your hands are sore, switch hands on 1 & 3 (boost 4) instead of spinning and stopping. For variation, try catching at angles, vertical or with creative free hand positions/action. Or try catching in a pose, lunge, or plié.

About technique

I hope you enjoyed this article! These techniques have helped my teams over the years. I learned them from my instructors, & supplemented with WGI equipment technique tapes. If you're already on a team, go with the techniques your team uses so you will adhere to your team's style. If what works for me doesn't work for you, please write me. I'd love to hear what others do or what might work better. If you want to contribute an article to be posted in our Instructor's Resources section, please contact me. Good luck, competitors!

*Fran Simmons * fran@colorguardfloors.com * Colorguard Floors*

Appendix F: Text Assignment

Exploring the Connection between your interest and physics

Now that you have found a text of your interest and learned the necessary physics concepts, it's time to explore their connection in greater detail.

Choose an interesting phenomenon or event that was mentioned in your choice text. Using the ideas you have learned in your physics class, you will elaborate and explain that phenomenon further beyond what was provided in your text. Some examples of phenomena can be: flight path of a soccer ball, football, golf ball; factors affecting the top speed of a racing car or maximum height of a tossed rifle; collision between cars, athletes, or racquet and ball etc.

For this assignment, you will produce a **two-page essay** consisting the following sections (you can attach additional picture or transcript as appendices if you need more than two pages):

1. A **description** of the phenomenon in the language of your interest area, e.g. football, colorguard, BMX, automobile.

2. A step-by-step **scientific explanation** of the phenomenon using the principles of physics. Your explanation should use the appropriate physics vocabularies and representations (e.g., diagrams, graphs) you have learned from the class. You are encouraged to read beyond what your were taught in order to fully explain the phenomenon, but this is not absolutely necessary. Whenever possible, apply relevant formulae and do some calculations. Use reasonable estimates for the numerical values based on your text and personal experience.

3. An **evaluation** of your choice text in comparison with your physics textbook. The requirement for this section varies according to the type of text you have. Choose **at least three** of the following options:
   a. An evaluation of the different vocabularies, units of measurements, or representations used in different texts. Why are they similar or different? What are the reasons and usefulness for different vocabularies, units, or representations?
   b. A critique of your text for any scientific error, inaccuracy, misleading fact, and bias. Be sure to support your critique with sound argument. (You should do this option if your text was created by a student).
   c. A summary of a portion of your text that simplifies it and makes it more accessible to a general audience. (You should do this option if your text was created by a specialist, such as a scientist, teacher, technician)
   d. A reflection of your learning experience in this assignment. What did you learn from your text? How will you read these texts differently in future? What further questions do you have? How will you address those questions?
   e. An evaluation of the different communicative styles (e.g., tone, expression, stances, humor) and organization adopted by the author. Why do the authors adopt different style and organization? What are their purposes?

You should focus on the first three levels of critical thinking for the explanation (i.e., Knowledge, Comprehension, & Application), and the last three levels for the evaluation (i.e., Analysis, Synthesis & Evaluation)

Scoring Rubric (You will be graded according to this scoring rubric)

	A	**B**	**C and Below**
Description (20%)	Able to identify an interesting phenomenon and describe it clearly and comprehensively. Define or explain terms that may be unfamiliar to a general audience.	Able to identify an interesting phenomenon and describe it somewhat clearly.	Provide a brief and general description that does not help a reader identify the phenomenon in question.
Explanation (40%)	Able to explain the phenomenon beyond what is provided in the student's text. Demonstrate a clear and accurate understanding of the physics concepts that were taught in class. Able to differentiate physics terms from their everyday meanings and use them in a precise and accurate way. Use relevant and accurate representations, such as diagrams, graphs, and equations, to enhance a reader's understanding of the phenomenon.	Able to explain the phenomenon beyond what is provided in the student's text. Demonstrate some understanding of the physics concepts that were taught in class. Able to use physics terms somewhat accurately in the explanation.	Merely repeat or reproduce the explanation provided in the student's text. Provide a vague and superficial explanation that has little or no connection with physics. Show a lack of understanding in the physics concepts and an inaccurate usage of terms and representations.
Evaluation (40%) (Not all of these items will be assessed depending on the nature of your text)	Able to identify the purpose of the author, and evaluate the text based on this purpose. Show a thorough awareness in the differences of language and representations between the text and those used in the physics textbook, and present a reasonable account for these differences. Able to identify major mistakes and biases in the text, and assess them critically based on evidence and sound argument. Able to provide a summary that is accurate and more accessible to a general audience. Ask thoughtful and insightful questions that enable a deeper critical understanding of the text.	Able to identify author's purpose, but does not evaluate the text based on this purpose. Show some awareness in the differences of language between the text and those used in physics textbook, and present no account for these differences. Able to identify some mistakes and biases in the text, but does not provide a critical assessment on them. Able to provide a summary that is somewhat accessible to a general audience. Ask reasonable questions that enable a better understanding of the text.	No mention of the author or his/her purpose in creating the text. Show a vague awareness in the differences of language between the text and those used in physics textbook. Unable to identify and assess major mistakes and biases, even when the text is replete with them.

The Physics of "Pumping" in Skateboarding
An Exemplar for Students

Description of Phenomenon

The main phenomenon in my article is about how a skateboarders can gain height and speed as they rise out of a "half-pipe". A half-pipe is a U-shaped ramp with a flattened bottom that allows skateboarders to perform stunts. A skateboarder would begin his stunt by "dropping in" or starting from the top of one side and going down. This generates the initial speed for the rider. Then the skateboarder maintains and increases this speed by "pumping" or crouching through the flat part of the half-pipe and extending their legs when they get to the vertical part. This allows the skateboarder to gain a little more speed and go higher and higher each time. (*Modified from Sean Womack's Journal Response*)

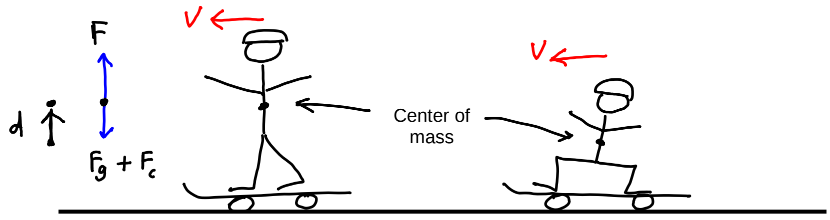
Scientific Explanation

After a skateboarder "drops in" from the top of a half-pipe, his **acceleration due to gravity** is 9.80 m/s^2 downwards. This means that as he falls, his **velocity** (taking downwards as positive) increases and he speeds up. This explains how the rider can generate a speed at the bottom of the half-pipe. Assuming negligible **drag** and **friction**, we can calculate this speed using the equation $v_f^2 = v_i^2 + 2g\Delta d$. The vertical ramp of a half-pipe is usually about 8 feet (2.5 m). At the point of dropping in, the rider's initial velocity is zero. Therefore,

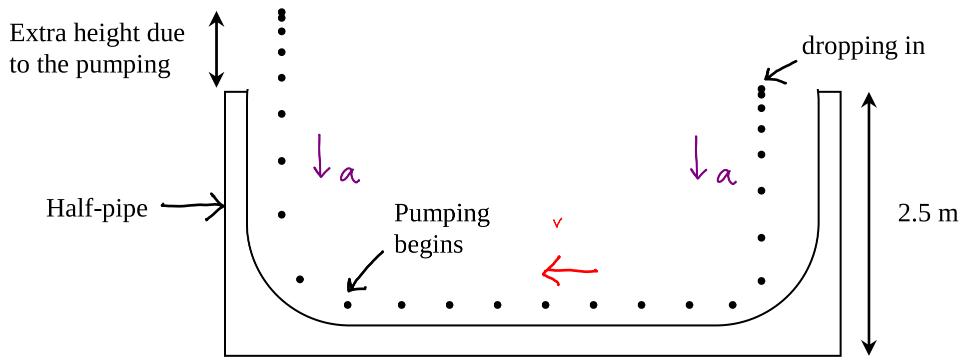
$$v_f^2 = 0 + 2\,(9.80\ m/s^2)\,(2.5\ m)$$
$$v_f = 7.0\ m/s$$

As the rider enters the opposite side of the half-pipe and goes upwards, his velocity is now 7.0 m/s (upwards) and is opposite the acceleration due to gravity. Thus he begins to slow down. In terms of energy, he loses **kinetic energy (KE)** as he loses speed. The lost in KE is converted to **gravitational potential energy (PE)** as he gains height. In a **closed system** with no drag and friction, the total **mechanical energy** of the rider is conserved. Therefore, as the rider loses all his KE, he gains back all his initial PE just before dropping in. As a result, he will reach a maximum height of 2.5 m on the other side of the half-pipe if he does nothing.

In order for the rider to jump higher than his initial drop, **work** must be done to the system. This is achieved by "pumping" as the rider raises his **center of mass** by extending his legs. The work done can be calculated by the equation W = Fd, where F is the upward **force** exerted by the rider against his **weight** and the **centrifugal "force"**, and d is the **displacement** of his center of mass upwards from his crouching position to his full height (see below pictorial model and free-body diagram). Because F and d are both in the same direction, the work done by the rider is positive. This means that extra energy is put into the system by the rider during pumping. This extra energy is thus responsible for the extra height he is able to achieve above the vertical ramp.



If we make a **motion diagram** by taking a series of consecutive images at equal **time intervals** and represent it using a **particle model**, his motion will look like this diagram:



Evaluation

This article titled "Skateboard Science" is written by a museum in San Francisco called the Exploratorium. It uses a mixture of skateboarding terms like half-pipe, pumping, Caballerials, and McTwists, and physics terms like net work, center of mass, and centrifugal force. The author also provides a glossary for these terms. However, the article does not use the other vocabularies that we learned from the textbook like displacement, velocity, and acceleration. Instead it uses layman terms like height and speed. I think the reason for this mixture can be explained by the goal of the museum, which is to educate a general audience about the science behind the things we do in our daily lives. Hence, the museum article does not get too technical. The textbook, on the other hand, uses more precise physics vocabularies so that we can use them to do calculation.

The museum article shows two real photographs of skateboarders jumping in the air. I think their purpose is to fascinate the audience as they are quite cool. Besides this function, the photographs do not aid much in the explanation of the phenomenon. They also do not help you to visualize the different parts of a half-pipe and how to do a pump. On the other hand, most of the pictures used in our textbook are abstract diagrams showing a sideway perpendicular view of the object (like a motion diagram). Although they are less interesting, we can use these diagrams to label all the vectors acting on the object to improve the explanation, like what I have done.

The tone used in the museum article sounds very similar to the physics textbook. Especially at the beginning of every chapter where the textbook tries to get you interested about the phenomenon it is going to explain. Like the textbook, there is no characterization, humor, and personal voice used in this article. Again, I think this has to do with the museum's goal to make its article sounds "scientific". At the end of the article, there is even an activity where you can do a demonstration with a string and coffee mug. The instructions given in this activity sounds a lot like those in the Launch Lab in our textbook.

Appendix G: Transcripts of Session with Lucy and Evelyn (21 April 2010)

1 (L and E talking softly to each other about the assignment)

2 (L noticed K was looking at them talking) L: Are we?

3 E:oh ya

4 ¤<22902>(0:00:22.9) K: oh, ok.. so what do you want to talk about?

5 ¤<26436>(0:00:26.4) L: um.. what::ever you want us to talk about

6 ¤<28950>(0:00:29.0) K: Have you all started to talk about. this assignment?

7 L: Yah. We [uh]

8 E: [Yah]

9 ¤<30621>(0:00:30.6) L: started talking about it, and um. when we started talking, we make sure we won't doing like. cos we're doing the same video, we decided to do different aspects↑ of it. A::nd um. we both doing tosses. but I'm doing it on rifle and she's doing it on flag, so it's different like.. the forces you put into it are different, and the forces that come out is different. And. the positions are all different, so it's basically.. like. a similar concept but it's different

10 ¤<54498>(0:00:54.5)E: Yah

11 ¤<55198>(0:00:55.2)K: Are you looking at different part of the text. the video that you are looking at. Or are [there] different segment?

12 ¤<58132>(0:00:58.1) L: [Um..] (L & E looks at each other)

13 ¤<60085>(0:01:00.1) E: well, they talk. mostly in the text they talk about like rifle tosses↑, but a lot of it on what they talk about apply in flag tosses too, just in a different way

14 ¤<68769>(0:01:08.8) K: I remembered your video has about. I think 3 segments, where the student is trying to talk about the different parts. So are you looking at the same part or?

15 ¤<77028>(0:01:17.0) L: I think.. we kinda looking at different aspects of the same part

16 ¤<80602>(0:01:20.6)(Brad walks over to the table)

17 because like. the segment of it were like. tossing.. center of.. gravity or something like balance, and.. I don't remember what the last one is, but I know those are the two major sections. And we uh.. we both focusing on tossing, we're just doing different aspects of it

18 ¤<96217>(0:01:36.2) E: yah

19 ¤<97335>(0:01:37.3) K: so only difference is because one is a rifle and one is a flag?

20 ¤<99589>(0:01:39.6) E: yah, [like the]

21 ¤<100621>(0:01:40.6) L: [yah but] like the (L & E looks at each other briefly) way they are weighted and the way they tossed are different. Like with the flag.. (L & E look at each other for 2s) um.. you're not trying to. Sorry, like the best way to explain it is on a rifle. The center of the rifle goes straight up and comes straight back down (L's finger trace a line forward and backward on the table)

22 ¤<111587>(0:01:51.6) K: And do you use both hands for rifle?

23 ¤<113408>(0:01:53.4) L: yah, you use [both] hands

24 E: [yes]

25 L: But then um..

26 ¤<115647>(0:01:55.6) E: For flag like. the center of the flag like it starts up here (both hands imitate holding flag position) and it's gonna basically go straight up and down. (RH index finger traces up and down)

27 L: but it

28 E: but. it ends up kinda curving (E's RH doing an arch) because it's like bigger. and like.. it does not. I don't know. it doesn't like rotate it's like (click?) (RH do a rotation motion)

29 ¤<127068>(0:02:07.1) K: And do you use one hand or two hands again?

30 E: two hands

31 ¤<130536>(0:02:10.5) L: And for mine, I'm gonna like. explore the difference between like. essentially like a perfect toss goes straight up and comes back down. (index finger traces up and down) But. in a toss that's like a mistake, where you use too much strength with one hand, it rainbows over (finger tracing an arch) and that's what we were talking about with the parabola. And so I am going to compare the two different texts and that doesn't happen (L & E looks at each other) in the flag

32 ¤<148130>(0:02:28.1) E: Yah, you can't really rainbow flag but um.. when you toss a flag like (hands imitate position). if you use too much of (LH imitates a swing down motion) one hand, it will just rotate right in front of your face (RH imitates rotation), so it has to be like. the forces is like. the way they add up like it has to be like more of this hand (LH swings downwards) to get the rotation around, then you have to have (RH raises up) more lift on this hand to get it go in the air (RH rotates), and do what you want it to do

33 ¤<168224>(0:02:48.2) L: If you exert an equal force on both hands, it doesn't move up (R index finger points up) or down

34 E: [yah, it just kinda like] (RH does a rotation)

35 L: [it just stay] (R index finger does a rotation) right in front of you

36 ¤<173405>(0:02:53.4) K: Okay, you know what will help me a lot, and. and I think will help you as well is to. draw what you just said. And so I'm going to give you some pieces of paper

37 L: [right]

38 ¤<178549>(0:02:58.5) K: [I] want you to draw. whether is it a rifle or flag and. draw some arrows and. talk to each other, and I want to see how it goes. [Okay?]

39 L: [right]

40 E: [okay]

41 ¤<186276>(0:03:06.3) B: Perfect. You read my mind (laugher)

42 K: well you see. we always think alike (laugher)

43 ¤<191669>(0:03:11.7) K: so just talk to each other. You know, how would you draw it and how would you explain with your drawing? And then I'll take a look.

44 ¤<198365>(0:03:18.4) (S passes papers for L and E)

45 ¤<198990>(0:03:19.0) K: (to S) thanks

46 ¤<205899>(0:03:25.9) B: feel free if you need to cross something out or scribe, or do whatever

47 ¤<209911>(0:03:29.9) E: do you have a pencil?

48 ¤<211025>(0:03:31.0) B: yah

49 ¤<215350>(0:03:35.4) L: Okay, this stick person.. (soft laugher) and.. (inaudible) and.. rifle.. (murmurs to herself as she started drawing)

50 ¤<228641>(0:03:48.6) B: actually, do you mind if I give you markers to write?

51 ¤<232145>(0:03:52.1) E: no (S pass them markers)

52 ¤<235344>(0:03:55.3) B: As we were watching, we are able to see what you are drawing at the same time? Not that is important, but..

53 ¤<241791>(0:04:01.8) (Naomi walked in and took Brad away)

54 (inaudible conversation between L and E as they draw)

55 ¤<277684>(0:04:37.7) E: Look at that. L: it's a good one.

56 ¤<280166>(0:04:40.2) (I walked over to Naomi's conversation)

57 ¤<286273>(0:04:46.3) E: Okay. So.. this is my gas

58 ¤<286699>(0:04:46.7) L: (looks over and laugh) Your gas?

59 ¤<288390>(0:04:48.4) E: Well, that's how I = (start? inaudible) right?

60 ¤<289209>(0:04:49.2) L: = Right, so essentially.. say which hand (pen points to E's drawing) is the gas and which hand (L looks at camera and pen points to camera) is the.

61 ¤<293123>(0:04:53.1) E: okay, well. my push down (LH pushes downwards) is the gas, and this (RH raises up) is my steering, so

62 ¤<298020>(0:04:58.0) L: your height

63 ¤<298957>(0:04:59.0) E: my. (laughs) okay

64 ¤<300141>(0:05:00.1) L: oh no, I'm just. (pen points at camera) I'm like I'm explaining it to the. (Lucy looks at the camera)

65 ¤<302050>(0:05:02.1) E: (Evelyn looks at the camera) oh

66 ¤<302338>(0:05:02.3) L: the video

67 (Evelyn drew an arrow up on left side and arrow down on right side, while Lucy looked on)

68 ¤<307846>(0:05:07.8) E: okay, this is.. my HEIGHT.. This is my. rota::tion(wrote height and rotation)

69 ¤<317746>(0:05:17.7) L: Right, so which hand uses more.. which hand. (L shakes her head) has more force.. if you are throwing a double

70 ¤<323708>(0:05:23.7) E: (sighs, seems like pondering) the height

71 ¤<325765>(0:05:25.8) L: yah (looks at and smile at E)

72 E: yah

73 L: yah

74 E: yah (laughs)

75 L: yah

76 ¤<329539>(0:05:29.5) E: This hand has.. more force (wrote more force on right side of diagram)(whisper) I don't know why..

77 ¤<337417>(0:05:37.4) E: cos if I. if it doesn't, then its just gonna.. be too low

78 ¤<340235>(0:05:40.2) L: Or, going to the ground if you use too much of the.. left hand than the other = hand

79 ¤<344034>(0:05:44.0) E: Right

80 (L looks at her own drawing)

81 ¤<346862>(0:05:46.9) L: alright and.. (looks over at E's drawing) on mine, the.. (re-enacting) left hand is the lift and..

82 L:(wrote lift on drawing)

83 ¤<353170>(0:05:53.2) E: the same isn't it?

84 ¤<354817>(0:05:54.8) L: (re-enacting) No 'cos yours is the right hand is the lift (re-enacting), and left hand the rotation

85 E: okay

86 ¤<358705>(0:05:58.7) L: and my left hand is the lift, and my right is rotation (wrote).

87 ¤<363455>(0:06:03.5) Evelyn: (re-enacting) yah

88 ¤<365388>(0:06:05.4) K: When you say this is height and rotation, are you. uh. referring to the arrow?

89 ¤<370096>(0:06:10.1) L: = this hand goes up

90 E: = this hand controls the height

91 L: and that one goes down

92 E: and this hand controls the rotation

93 ¤<374510>(0:06:14.5) K: okay, so that is the function of the hand, right, or the purpose?

94 E: yah

95 L: yah

96 ¤<378238>(0:06:18.2) K: same for you as well right?

97 L: yah

98 ¤<378627>(0:06:18.6) K: so what is this arrow that you are actually drawing?

99 ¤<380288>(0:06:20.3) E: well, this would be like.. my push down (RH moves down) because when you like toss. my flag, I have to push down (LH moves down) with my right hand to get it to [rotate]

100 ¤<386906>(0:06:26.9) L: [left] hand

101 E: like. that's my force down.

102 ¤<388603>(0:06:28.6) K: okay, your force down.

103 E: (whisper to L) left hand (inaudible)

104 ¤<390735>(0:06:30.7) E: And then, the other hand would be like. my height like. getting up there

105 ¤<394893>(0:06:34.9) L: and like. in rifle.. before you toss, like there is a prep. So like instead of tossing from. flag up and down, you. like. gain your momentum↑ by like. basically.. like. preping (both hands enact position) [like to get ready]

106 ¤<407796>(0:06:47.8) E: [it's like a. it's] called the dip. Like. you get start up at an angle, (both hands enact position) so you get more.. (RH lifts up)

107 ¤<411363>(0:06:51.4) L: (Looks at her diagram) So like the.. the speed you get going down and coming back up. gives you.. the.. (L facial expression; looks at E) momentum? The mo.. hmm.. no, I don't think it's momentum. It gives you the.. energy you need. [to.]

108 E: yah

109 L: be able to get it around

110 ¤<423498>(0:07:03.5) K: okay

111 ¤<424470>(0:07:04.5) E: and like.. but on flag, you already start at your angle. (both hands enact position) And. you like use the time like to take you back up into the air (LH raises up) to like build like momentum or energy or whatever

112 ¤<434419>(0:07:14.4) K: So you saying that uh. when you toss your rifle, you have. there's more time. for you. from that position to when you release it?

113 (E nods)

114 ¤<440995>(0:07:21.0) L: Alright, you start here. (both hands hold imaginary rifle horizontal). You go down (dip position). And then you release (both hands flip).

115 ¤<444497>(0:07:24.5) K: Yah, exactly. So. so there's more time you're. you are [holding]

116 E: [yah]

117 K: the [rifle right?]

118 L: [Yah]

119 ¤<447371>(0:07:27.4) E: [it like increases] the time. (both hands holding position) to like.. (LH lowers and RH raises up) build up the momentum and energy before you release (RH raises up) so like it goes higher like and spins (inaudible)...

120 ¤<453209>(0:07:33.2) K: whereas for flag, you don't have it, you just throw right?

121 L: yah

122 E: yah

123 ¤<456732>(0:07:36.7) L: It's right from = right there (enacting)

124 K: = you don't.. you don't

125 E: the flag is already there at that angle

126 K: you just throw

127 E: yah

128 K: Got it

129 L: because you don't need like the extra energy because the flag is lighter

130 K: that's a good point. very good

131 ¤<470949>(0:07:50.9) E: and like with er. rifle, if you just throwing a low toss, you don't have to dip. You just start from here and toss. And you get up to um, if you are throwing a single, even a double, you can throw a flag. But higher toss, like if people do a 6 and 7, you need the dip, there's like even different dip, like.

132 ¤<489554>(0:08:09.6) L: Like sometimes if you are throwing a really big toss (points to new diagram), you go all the way straight up and down, and you can throw not this big of a toss, you doesn't have to go all the way

133 ¤<497124>(0:08:17.1) K: So do you think this is related to impulse theorem? impulse-momentum theorem? I know you just learned that.

134 ¤<501197>(0:08:21.2) L: okay, well impulse-momentum. Okay. I have trouble on this, so explain to me a little bit more about momentum. Impulse-momentum is when it hits something (punched fist in hand) and bounces back off.. [Right?]

135 ¤<508994>(0:08:29.0) K: [Yes.] But it can also include uh. throwing something.

136 E: [okay]

137 L: [Okay.] how.. does it work if its [supposed to (?)]

138 ¤<514684>(0:08:34.7) K: [Write down the] mo. uh. write down the equation, which is f. you know the impulse-momentum theorem. F change in delta t, the triangle delta t

139 ¤<520757>(0:08:40.8) E:oh wait, we're not. Are we talking about the work one?

140 K: = no, the last chapter

141 L: = (inaudible)

142 ¤<525300>(0:08:45.3) E: oh. No, I didn't get last chapter

143 ¤<526413>(0:08:46.4) K: So force multiple by, yah write down the equation, force delta t equals to final momentum, which is m v f, momentum is mass times velocity, or it's m v f

144 L: okay

145 K: minus your m v i

146 L: (whisper) got it

147 K: v i is initial velocity

148 E: yah

149 K: whihc is zero because it starts from rest

150 E: okay

151 K: right. So now look at this equation. You have force, you have time. And the time means the time of contact you are holding the rifle or push the rifle (I gesturing; they looked)

152 E: so it's like

153 ¤<560602>(0:09:20.6) K: once you let go (announcement), the time is (inaudible)

154 E: yah

155 K: so time is from your starting position to the time you release your rifle or flag. okay

156 ¤<568592>(0:09:28.6) K: and then, mass is of course the mass of the rifle or flag. and your. Now this final velocity is actually the velocity when you released it

157 ¤<582942>(0:09:42.9) E: okay. So will the initial velocity will be zero because you start (reenacting)

158 K: that's your beginning position. let's say you're here(point to L's dip diagram) right?

159 L: okay

160 K: So this will be your v i, which is zero. And when you tossed it (enact), and this will be your v f (points to push position) because it is the final position when you release the rifle

161 ¤<599151>(0:09:59.2) L: Um, actually, you let go in one hand, and the other hand, its actually um (draw new diagram).

162 K: so draw that, yah, draw that in your diagram

163 ¤<607576>(0:10:07.6) L: er, you let go the gun like at this angle.. over here, so there.

164 ¤<617455>(0:10:17.5) K: okay, so the time from here to here (pointing at Lucy's drawing) is delta t, that's the time [when]

165 L: [okay]

166 K: you are preping (reacting). you are throwing the thing. And the time is uh. what do you estimate is that time.. in your experience?

167 ¤<624904>(0:10:24.9) L : half a second

168 E: yah

169 K: yah, it should be very short right. I don't presume you take very long (I enact a toss)

170 E: It's like a count, so like a second

171 L: dut dut

172 E: dut dut, yah

173 ¤<633003>(0:10:33.0) K: I think it's less than that. I think you are right (point to L), that's about half a second, you know your mass, so you can actually find out what is your force that you have to exert (reenact), and actually the velocity. (point to their diagrams)

174 ¤<646181>(0:10:46.2) K: now, can you find out what is your velocity of your release?

175 L: well, velocity is what? velocity is..

176 E: dis... displacement over time

177 ¤<660275>(0:11:00.3) L: okay, so... wait distance or displacement

178 K: well, it's actually your height right?

179 E: so it will be like how high our flag goes over the time. Is it the time that from our release point?

180 ¤<678804>(0:11:18.8) K: you can decide where you want the height to be

181 ¤<684579>(0:11:24.6) L: wait, are we doing from the time we are holding on until the time we let go?

182 ¤<687938>(0:11:27.9) K: no, this is different. This is the confusing part. Remember last time I talked to you there are 2 stages? Stage 1 is from your prep position to when you release, that is when you are still holding the rifle. The second part is when you let go of the rifle now, and now the rifle is flying up in the air. So it's a different time now. So now your initial is when you release, and your final is where you are at your top.

183 ¤<713440>(0:11:53.4) L: So we are talking about stage 2 now?

184 E: we are talking about this one (points to her drawing)

185 K: stage 2 yah

186 Both: okay

187 L: okay. So we are tossing

188 ¤<714996>(0:11:55.0) K: so let's draw a diagram, and see if it makes sense? So stage 2 is your beginning, and then you throw it up

189 L: okay, so guh-guh (drew dots). And then it should come back right back down and.
190 E: the same
191 L: the same
192 ¤<728909>(0:12:08.9) K: so you take this as initial and this is your final, and then you know the height here right?
193 ¤<733029>(0:12:13.0) L: [smiling] uh, let's see... (L & E look at each other) It's a quad
194 E: okay
195 L: right, I'm trying to think about a triple rotates right above your head
196 E: yah
197 ¤<747911>(0:12:27.9) L: A quad rotates
198 E: well, where do you release a quad
199 L raises LH aligned with her mouth
200 E: yah, then it should be
201 L: and that's 5 feet high. And assuming it moves 3 feet above that? So let's say we're 8 feet above the air
202 ¤<761663>(0:12:41.7) (L drew 8 feet from top to floor)
203 K: To here. when you release, not when
204 L: oh, you want =
205 K: = you don't count your own height
206 L: okay
207 K: you need to account.. you subtract your own height
208 E: so your release so
209 L: 3 feet
210 E: 3 feet
211 (L drew 3 feet)
212 E: well, I need to figure out for a flag
213 K: Yours might be different
214 L: go for it
215 E: I don't know how high it is
216 L: double
217 ¤<781619>(0:13:01.6) L: okay, I know when I throw my turnaround, that would hit the middle beam in Scrapps
218 E: yah, but you throw really high
219 L: I threw really high. That's why I'm thinking backwards
220 E: because I don't know how high a double should actually be
221 ¤<796138>(0:13:16.1) L: oh we're taking about the center of the flag. We have to remember that too though
222 E: yah, well
223 L: so it's not the top
224 E: your hand still on the (inaudible) so..
225 L: hmm
226 E: it's already in the center

227 L: But if you are measuring the center, that's like half foot less than the highest point

228 ¤<809710>(0:13:29.7) E: I don't know..

229 L: I say.. it's goes higher because it got a

230 E: it does.. it goes higher.. but I don't know. probably 5? 6 feet? I don't think it goes higher

231 L: let's say 5 feet. 5 feet above

232 E: okay.

233 ¤<834437>(0:13:54.4) E: (drew and wrote down 5 feet). Okay. mine goes up, say, come straight down. Mine is like.. 5 feet-ish

234 ¤<841418>(0:14:01.4) K: so good. You have more information now. So with this information, can you find what is your velocity in this? your rifle or your flag?

235 L: right, time would be

236 ¤<853417>(0:14:13.4) K: well, it's not that equation, you don't need time. This is where you need to go back to chapter 3. (they laugh. Lucy opens file and ask which equation to use)

237 K: this is where the physics comes in

238 ¤<864507>(0:14:24.5) L: okay. which equation are we using?

239 E: the one that don't have time in it

240 K: Find one that doesn't have time because... you could have if you calculated your own time but there's one equation without the time

241 ¤<876899>(0:14:36.9) E: because we could calculate time

242 K: you could, you could yah

243 L: think that might be easier

244 ¤<879634>(0:14:39.6) E: yah, cos. yah, cos you know the counts of [(inaudible)]

245 K: [okay, sure]

246 ¤<884210>(0:14:44.2) L: okay.. so. okay so a quad is.. (L & E look at each other. laugh) Okay, this is going to sound stupid. Right. (murmuring in low voice) five, six. five, six, seven, eight (hands flipped). One, two, three, four, and hit. So that'll be..

247 ¤<892715>(0:14:52.7) E: five seconds?

248 ¤<894220>(0:14:54.2) L: dut-dut-dut.. yah, five seconds

249 ¤<895599>(0:14:55.6) E: yah

250 L: right?

251 E: yah. five seconds

252 L: okay, so assuming this takes. okay..

253 ¤<908798>(0:15:08.8) E: I want to say

254 L: it's longer?

255 E: yah. Cos it's eh. Okay, cos we started here and we do a little. I forgot about that actually.

256 L: assume you are not doing that

257 E: okay

258 (L and E enacts a toss and estimates timing)

259 ¤<922320>(0:15:22.3) L: that's 5 seconds again

260 E: no. cos it's 5-6-7. AND one. I release on one. so that's actually 4 seconds

261 L: okay. fair enough

262 E: yah

263 L: okay. So.. (L wrote on her paper) minus 3 feet divided by..

264 E: but..

265 L: 5 seconds

266 E: it's supposed to be meters

267 ¤<948240>(0:15:48.2) K: Okay, hold on. Before you go there. This equation assumes that there is no acceleration. But when you are throwing things up and down, remember you have to deal with?

268 L: er, gravity

269 K: gravity. so you can't use this one b'cos you are assuming there is no acceleration

270 ¤<957081>(0:15:57.1) E: yes, don't you have to use that 9.8..

271 K: that's right, that's the missing information

272 E: okay, so we do have to do this one (points to which formula?)

273 ¤<966315>(0:16:06.3) K: And actually, there's actually a relationship between the height and your time. If I know your height, I can actually know your time.. There's actually a formula to you to do that. And vice versa, if I know the time, I can actually know the height.. So actually I can check whether those two are consistent.. Right now, you are estimating it right? (Lucy looks intrigued/puzzled)

274 E: yah

275 ¤<984413>(0:16:24.4) L: well, how do you know that if we don't know our velocity?

276 E: we are estimating the height

277 K: because you don't need to. Because I know that um

278 L: but I can change this

279 E: because he knows the acceleration

280 L: like I

281 E: because he knows like how gravity works on the object, can find

282 ¤<1004023>(0:16:44.0) L: wait, but how can you assume it b'cos I can have

283 E: no, because he knows how gravity acts on the object, so if he knows how high it is, he can find the seconds

284 L: wait, but if you know the height of us, or the height of the toss?

285 K: height of the toss

286 L: okay, okay

287 K: it's always from where you release the thing to where it reaches the final maximum height

288 L: okay

289 ¤<1022541>(0:17:02.5) K: think back, it's in chpt 3, which formula do you have. You're right, you know Evelyn, you got it correct. I know the gravity

290 L: we're in chpt 2 right now

291 K: chpt 3. Still chpt 3

292 ¤<1034128>(0:17:14.1) L: okay, what are we figuring out?

293 K: figure out the relationship between the time of the toss and the height that you reach

294 L: okay. so...

295 ¤<1045383>(0:17:25.4) E: time, acceleration, initial velocity and your displacement, so you have the time, you can get displacement, you get displacement, you get the time

296 ¤<1054752>(0:17:34.8) E: okay now, this would be useful to know like when I took the test

297 K: oh, that's good.

298 L: alright, so our distance. So we are assuming this is zero... right?

299 ¤<1066989>(0:17:47.0) K: no, this is no zero (L looks puzzled). It's a bit more complicated. Let's assume that instead working from where you release to where you reach the height, lets' work backwards. Let's assume that.. this is your initial, and you dropping it from the height and it's coming down.

300 E: so..

301 ¤<1082638>(0:18:02.6) K: cos remember when you throw things up, the time it takes for the thing to go up is the same for the time to come down. Do you remember that?

302 L: no. I don't remember anything, that's why I failed the final

303 ¤<1092918>(0:18:12.9) K: but this is common sense. the time... would you agree wih that?

304 L: Ok, sure. If you say so.. I don't remember it

305 (E and L looked at the formula book and engaged in conversation. School announcement; inaudible)

306 E: I don't have my.

307 L: okay (walked to front of classroom to get calculator)

308 E: actually I have one on my..

309 ¤<1129402>(0:18:49.4) K: so you wish you learned physics from colorguard?

310 ¤<1130645>(0:18:50.6) E: yah. Well, it actually just makes sense now that I understand like acceleration better, like I don't know, that makes more sense now

311 ¤<1141001>(0:19:01.0)(L brought 2 calculators)

312 ¤<1145406>(0:19:05.4) K: okay now, let me give a simple question. Instead of going from here to up. Let's imagine if an object is dropped. You're dropping an object from 3 feet. With that information, if I drop something at 3 feet, how long does it take for the object to touch the ground?

313 ¤<1166948>(0:19:26.9) (L calculated from her notes)

314 K: where did you get that from?

315 ¤<1173735>(0:19:33.7) L: This is what I couldn't find when I was taking the test, that's why I got 8 problems wrong

316 ¤<1178132>(0:19:38.1) K: This is actually derived from this equation. I'm not sure if you make the connection

317 L: I probably didn't

318 E: yah
319 K: but you let v be zero because when you release it.
320 E: your
321 ¤<1189265>(0:19:49.3) L: your (inaudible) equals zero
322 E: yah
323 K: so the two (inaudible) so did you see it's the same?
324 L: yah
325 ¤<1208728>(0:20:08.7) L: So I have 2 times 3 feet.. (L wrote on her sheet)
326 K: did you convert to meter?
327 L: yes, I do.
328 L: (to E) I will convert mine, and you convert yours
329 E: Right. So I have 3 feet and so (inaudible)
330 ¤<1226838>(0:20:26.8) L: It's only a meter. 3 feet can't be right.
331 ¤<1230642>(0:20:30.6) E: no, you're thinking of it.. so you start from your hand. yeah, that's more than 3 feet
332 L: That's right. Or. or triple might be.. it doesn't really..
333 E: well because.. okay, we start here. and it's above your head (E gestures toward ceiling)
334 ¤<1243693>(0:20:43.7) L: a triple. a triple
335 E: so let's say we get triple.. so mine is definitely a..
336 L: single?
337 E: right
338 ¤<1249090>(0:20:49.1) L: okay. whatever. Uhm. what is my meters?
339 E: point nine one
340 L: point nine one? okay. So
341 (L and E scribbled notes in their papers and murmured to themselves.)
342 ¤<1272648>(0:21:12.6) L: we actually need to measure our toss
343 E: I know
344 L: for this project. okay.
345 ¤<1278219>(0:21:18.2) E: like actually watch it go up
346 L: I know
347 ¤<1280719>(0:21:20.7) L: okay, what's y?
348 E: wait. what did you.. (inaudible)
349 L: this one. (L drew a box around her equation)
350 E: oh
351 L: I'm finding if I drop it with here
352 E: oh. okay
353 ¤<1289514>(0:21:29.5) K: 3 feet is .91 and 5 feet is 2.44?
354 E: no. it's eight now
355 K: oh, eight feet. okay, sorry
356 E: cos. our guesstimation is way off.. okay
357 ¤<1298362>(0:21:38.4) K: so what is the time that you get?
358 ¤<1302050>(0:21:42.1) L: wait, what's y stand for?
359 E: your y.. factor?

360 K: it's actually not a y, it's actually a d subscript y
361 E: oh yah
362 L: oh, okay
363 K: it's d in the y direction
364 L: nine point eight (L wrote in her paper)
365 ¤<1316084>(0:21:56.1) E: (points at L's writing) so are you finding out if your seconds are like. correlating with your height?
366 L: yah. I'm figuring out how long it should take for that tap and. (L pressed her calculator)
367 ¤<1331552>(0:22:11.6) E: isn't that little g?
368 K: yah, it's little g.
369 E: (to L) that's little g
370 L: okay. I write caps in all the time
371 ¤<1342393>(0:22:22.4) L: so that's .43 seconds
372 K: so is that correct?
373 L: no, it's not. it has to be more than 3 feet.
374 K: I think. Yah, I think it has to be more than 3 feet. I think 3 feet is very short
375 ¤<1353403>(0:22:33.4) E: but you are doing a quad now? or triplet now?
376 L: even a triplet is more than 3 feet
377 K: yah. triplet means you turn 3 times right?
378 L: yah
379 K: I think it's more than 3 feet
380 ¤<1361784>(0:22:41.8) L: feels like 5, 6, 7, 8. dut-dut-dut-dut-dut. it depends on the tempo
381 K: so actually you can work backwards. if you know the time, you can actually work backwards to calculate the height.
382 ¤<1370045>(0:22:50.0) L: Right. So assuming.. the time is 5 seconds
383 E: is that the right time?
384 L: yah, 5 seconds, that's right
385 K: oh, that long?
386 E: okay. so should I do? I'm going to (inaudible)
387 ¤<1385693>(0:23:05.7) L: 8 feet sounds (inaudible) enough. (look at clock.) I have to go soon
388 E: so do I
389 (E and L works on their calculation)
390 E: oh really? cos I end up being about 5 seconds. and that's what we said
391 L: okay. go for it. sure
392 E: yah, so close. So my time is actually
393 ¤<1402843>(0:23:22.8) L: so that means a quad is 8 feet too? cos that's sounds like?
394 E: yah. wow. I thought..
395 ¤<1412762>(0:23:32.8) L: think about it though
396 ¤<1416857>(0:23:36.9) K: It can't be right? 8 feet is 4.9 and 3 feet is 4.3

397 E: yah. Because. I mean
398 L: .43
399 K: and this is .49?
400 E: yah, it's .49. Oh wait..
401 L: so one of our math is wrong
402 K: one of your math is wrong
403 ¤<1430565>(0:23:50.6) E: oh I meant. That's not what I meant. That's what I meant. 4.9
404 ¤<1441021>(0:24:01.0) L: did you square root your answer?
405 K: did you square root? yah
406 E: oh, I didn't square root.. .7?
407 K: It can't be. square root of 4.9 should be around 2. something
408 E: oh okay. Let me try it again..
409 ¤<1467267>(0:24:27.3) L: maybe I should do center of gravity
410 K: point seven
411 ¤<1468938>(0:24:28.9) E: So its like.. my time will equal point.. seven. Alright.. But (looks at K)
412 ¤<1476496>(0:24:36.5) K: Hmm, doesn't make sense right?
413 ¤<1478947>(0:24:38.9) E: No.. 'cos it's not in. it's in the air for longer than 1 sec
414 ¤<1484789>(0:24:44.8) K: so maybe the height is more than that? (2 sec pause)
415 ¤<1487814>(0:24:47.8) L: we'll be hitting ceiling
416 E: yah (2 sec pause)
417 ¤<1490578>(0:24:50.6) K: Hmm
418 ¤<1491513>(0:24:51.5) E: well..
419 ¤<1496844>(0:24:56.8) L: We have to like. I think to do this, we have to go out and measure this first.. Or let's see, let's try the working backwards thing, if the time is 5 seconds, assuming it's a rifle toss and the count is 5 seconds. (L turns to E) But it's not 5 seconds, it's 5 counts.. Each count is not a second.. Dut-dut-dut-dut-dut-hit. dut---dut---dut-hit. That's not 5 seconds.
420 L: = okay
421 E: = okay
422 ¤<1514381>(0:25:14.4) L: you look at the clock, and I'm going to count
423 E: what? that's not going to work?
424 L: count how many seconds (point to clock)
425 E: I can't even see it. I don't have my glasses on
426 ¤<1527541>(0:25:27.5) (L looks at the clock) dut-dut-dut-dut-dut-hit. 5 counts is like.. (looks at E) 2 seconds.
427 E: oh
428 L: that's = why we have problems
429 E: = seems like longer when you tossing it, doesn't it
430 K: (laughing) yah
431 E: actually, it doesn't
432 L: I think

433 E: it's not (inaudible). the answer is probably right

434 ¤<1541118>(0:25:41.1) L: I don't think we can do this until we have..

435 K: yah, I think as long as we got the formula right, all you need is the numbers

436 L: yah

437 E: yah

438 K: I probably look at some video and look at the time

439 ¤<1547828>(0:25:47.8) E: well, that looks right

440 K: so all you need is the time it takes for it to go up and come down

441 L: alright

442 K: and this formula is correct. Once you have your time, you can put it back and calculate your height

443 ¤<1565631>(0:26:05.6) K: but I think you know the gist of it right?

444 L: yah

445 K: the physics behind it.

446 E: what has all these got to do with this one?

447 K: yah, good question. Once you got all these right, you can find your..

448 E: my force?

449 K: velocity when you.. no, the velocity first when you release it

450 L: okay, so why did we need to find the velocity?

451 ¤<1582487>(0:26:22.5) E: = so, we need to find the time.. and put it into this

452 K: = Then, you can find the time to put it (E & I put to L's equation for Ft = Mvf - Mvi

453 L: to find the force, and then we have the time, and we can get this out

454 K: So the force is the force you actually exert on..

455 E: wait wait.. so this is.. (some confusion with the time Dt as the time they just calculated for the falling object)

456 ¤<1607866>(0:26:47.9) E: okay. Oh okay okay

457 ¤<1629497>(0:27:09.5) K: There is one thing I want you to be careful about. Now these 2 forces right, if they are equal, what will happen?

458 Both: it will rotate right in front of you

459 K: correct. So one will have to be higher than the other one

460 E: yah, this one has.. Is it greater force, or is it just because you lift your hand? Like you release it high, it goes..

461 K: it's the same thing right, I mean. it has to be a higher force

462 L: You have to use more force to (RH raises up)

463 E: okay

464 ¤<1671167>(0:27:51.2) K: so work on it. And see if you can get some answers

465 L: okay.

Appendix H: Evelyn's Essay

Evelyn

4/28/10

4th hour

The Physics behind Color guard

The phenomenon that I'm focusing on from my text is the force that goes into a double on flag. In a double the flag rotates twice once it is released. The traditional flag is a 6 ft. pole with weights on both ends. The bottom weight is larger than the top weight to help build momentum when you're tossing. The silk is 52in. by 36 in. It can be made of a lot of different fabrics that sometimes weigh differently. The difference in weight can affect the force you need to put into the flag to make it go around. When throwing a double your left hand pushes down on the flag giving it the rotation you need. Your right hand lifts the flag up and gives the flag the height and direction.

The main goal is to get the right amount of force so that the flag goes around the right amount and is the right height. You also want it to go straight up then straight back down. If the flag goes out to the side it is called "rain bowing".

Scientific Explanation

To find the force that is needed to toss a double you need to use Newtons second law

$$F_{net}=ma$$

The mass of a flag is approximately 1.59 kg. To find the acceleration of the flag you need to get the change in velocity and divide it by the time in which the change took place:

$$a = \frac{\Delta v}{\Delta t}$$

Because the Kinetic Energy at the bottom of the toss or where you release, is equal to the Potential Energy at the top of the toss or the highest point you can find the velocity (KE=PE). The potential energy is equal to the product of the mass, the acceleration due to gravity ($9.8m/s^2$) and the difference from the reference level, which in this case is 8ft or 2.4 m. Therefore,

$$v=2(9.8\ m/s^2)(2.4m)$$
$$v=6.9\ m/s$$

The velocity is 6.9 m/s. The time it takes to release the flag only takes about .25s. Finding the acceleration of the flag is just punching in the numbers

$$a = \frac{6.9\ m/s.25s}{} = 27.6\ m/s^2$$

With both the mass and acceleration you can find that the force used to get the flag up in the air is 43.9 N. Because you hands are working in opposite direction the right hand has to have more force than the left in order for the flag to overcome the downward force and go in the air. 43.9 N is the net force which is the sum of all forces acting on an object.

Evaluation

The text that I found was created by a high school student for a physical science project. They use a combination of physics terms like force, acceleration and velocity along with commonly used terms in color guard, like your center, arch's or rainbows. It has some errors in it aside from spelling; there are definitions that are not very accurate. For example acceleration is not just causing something to move faster, it is the rate in which an object's velocity changes. Also some of the concepts they explain are right in sense but don't encompass all of the elements explained. Some of the concepts are simplified so much that they leave out really important information.

The tone of this text is nothing like a textbook. They use very laid back language and even have really good music playing in the background. I think because it was made by students they were not aiming to be too scientific, but it did help me understand some of the concepts before learning them in class. This text has both humor and a personal voice that makes it easy to pay attention to. It is similar to some of the videos we have watched with out being to cheesy.

I did not learn to much from my text because so much of the information was incorrect or left things out. Though I didn't learn much, it did make me more interested in what we were learning in class. I liked hearing about something that is very important in my life related to the topics we were talking about. I also liked how the text was easy to understand and pay attention to. In the future I know that I am going to have to be careful about what text I listen to because not all of it is accurate.

Appendix I: Lucy's Essay

Lucy
May 3, 2010
Honors Physics

Physics in Colorguard

Description of Phenomenon

Colorguard is an activity that involves a lot of physics. Every time a Colorguard member moves or tosses, they must take into consideration the affects of gravity and several other physics related concepts. For this study I intend to focus on the tossing of a rifle quad. I will explore a perfect toss.

Scientific Explanation

A rifle is a piece of equipment used in Colorguard. It is made of wood, and on an average weighs approximately 2.2 pounds. A rifle is tossed using an upward force with the left hand and a downward force with the right hand. When an equal forge is exerted with both hands, the rifle rotates in place and the result is a single. A single is when the rifle makes one rotation before being caught at the same height it is released. Likewise a double makes two rotations, a triple three and a quad makes four. When a higher toss is desired the member exerts a greater force with their right hand and raises the left hand to a higher release point. For the purpose of this study I intend to focus not on the rotating object but on the point at which it pivots. This point will be used to represent the rifle without having to look at the entire object's rotations.

In a perfect quad the pivot point of the rifle goes straight up and comes directly back down. The physics behind it is the same as a stone thrown up and returning back down. As the rifle travels upward the acceleration due to gravity is -9.8 m/s^2. The energy that the tosser exerts on the rifle must be able to overcome acceleration due to gravity. Because kinetic and potential energy will be equal, we simply need to calculate one or the other to know what both potential and kinetic energy would be. Before we calculate energy it is important to calculate what the weight of the rifle is in kilograms. One pound equals 0.45359237 kilograms, so a 2.2 pound rifle weighs approximately 0.9979 kilograms; which for the purpose of this study we will round to one kilogram.

PE=mgh
PE=(1kg)(9.8m/s^2)(1.76m)
PE=17.248J

Work equals the change in kinetic energy, which means a guard member must exert approximately 17.25 joules of energy to overcome the 9.8 m/s^2 acceleration the earth exerts on the rifle. The rifles upward energy is overcome in .6 seconds; at which point the rifle begins its decent back down to the tosser. This time can be confirmed by the equation $\sqrt{2dy/g}$.

$$t=\sqrt{2dy/g}$$
$$t=\sqrt{2(1.76m)/9.8m/s^2}$$
$$t=.599sec$$

Higher tosses require more energy from the tosser. Because of the greater force exerted, it takes the acceleration of gravity longer to overcome it. Therefore, the time and height is grater with higher tosses.

Evaluation

The tone that the author chooses to use in this video is quite simple. She uses text book definitions and surface explanations to convey her message. She is obviously making this video as some sort of project. It also seems as though she is operating in a very low-tech situation. Her visuals are not videos but nonmoving images. Although it is quite possible for me to understand what is going on in the images, I could see how it would be hard for someone who does not have an in-depth knowledge of Colorguard to understand what is going on. Videos would be a much more affective form of communication for this video. It would make it much more enlightening, and interesting if it was enhanced with videos. To me, it appears as though our author found herself holding off on doing this project until last minute. It is quite possible she found herself spending too much time at Colorguard practice, and not enough time working on her Colorguard project.

Because my text was created by a student, quite possibly one in a last minute pinch, it is not perfect. She spends a lot of time focusing on center of gravity. This is a concept that is existent in physics, but I believe she spends much more than the necessary time on it. My speculation is that her video had to be a certain length and she used this simple concept to fill her time with miner effort. On an unrelated topic, at minute 2:48 the author prints the phrase "The acceleration the girl exerts on the flag goes the same way the force does." Along with the fact that the sentence is worded rather immaturely, the author also misuses the word acceleration. The term that the author was looking for was force. Acceleration cannot be used to describe what she is doing because acceleration describes things like the earth's gravitation. A force is what it takes to move an object. "The force that the girl exerts on the flag creates motion in the desired direction" is the wording I would use in this situation.

This assignment forced me to combine my knowledge of Colorguard and physics. It also taught me to apply physics into my everyday life. As a result of this project, I look at the way I do things in Colorguard a little differently. My new knowledge makes the way I practice a little more affectively; I know exactly the force I need to apply to complete the task I am aiming to complete. I hope next time I look at a physics text it will combine the youthful spirit of work done by student, but lack the mistakes and immaturity that come from nonprofessional work.

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