UNIVERSITY OF CALIFORNIA

Los Angeles

Pedagogy Matters:

Engaging Diverse Students as Community Researchers

in Three Computer Science Classrooms

A dissertation submitted in partial satisfaction of the

Requirements for the degree Doctor of Philosophy

in Education

by

Jean Jinsun Ryoo

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ABSTRACT OF THE DISSERTATION

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Doctor of Philosophy in Education

University of California, Los Angeles, 2013

Professor Peter McLaren, Co-Chair

Professor Ernest Morrell, Co-Chair

Computing occupations are among the fastest growing in the U.S. and technological innovations are central to solving world problems. Yet only our most privileged students are learning to use technology for creative purposes through rigorous computer science education opportunities. In order to increase access for diverse students and females who have historically been denied these opportunities, a course entitled "Discovering Computer Science" [real names were changed to protect participant privacy] was introduced to Metro City Unified high schools in 2008. During the 2011-12 school year, the "MyData" Unit—in which youth conducted community research using mobile phones and statistical analysis software—was added to the curriculum.

While quality curriculum is important, this curriculum's success depended on *how* it was engaged. Thus, through a qualitative case study of three classrooms chosen for their strong teachers, I examined what *effective teaching* and *student learning* looked like through the MyData Unit. Guided by Cultural Historical Activity Theory and critical pedagogy notions of learning while employing interpretive participant observation, critical ethnography, and multimodal methods to analyze data sources (observation field notes, video recordings, student surveys, teacher and student interviews, student projects, a researcher journal, and memos), I describe pedagogy that engaged diverse students with computer science practices and how students demonstrated these practices.

Effective teaching included what I define as a "Connected Computer Science Pedagogy" (CCSP) and the use of humor. CCSP involves: 1) making computer science personally relevant; 2) highlighting how computer science can address social issues; and 3) engaging collaborative learning. Humor proved valuable for 1) motivating student learning; 2) making learning less stressful; 3) building classroom community; and 4) mediating disciplinary situations. Key features of student learning included new understandings of data as well as feeling empowered as community researchers. Yet students demonstrated a range of ability with data analysis and computer science practices in their final projects.

This work fills a research gap regarding effective computer science pedagogy. My findings emphasize how computer science education can move beyond a mere fascination with technological tools toward learning that is driven by curricular content, strong teaching, and community interests.

The dissertation of Jean Jinsun Ryoo is approved.

Mike Rose

Kris Gutiérrez

Joanna Goode

Jane Margolis

Peter McLaren, Committee Co-Chair

Ernest Morrell, Committee Co-Chair

University of California, Los Angeles

2013

DEDICATION

To my family, both given and chosen,

and

to the teachers and students who shared their classrooms with me.

You inspire me every day.

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ACKNOLWEDGEMENTS

Our name—Ryoo (류)—means "willow tree." This representation of my ancestry is most fitting for my family whose tough roots have taught me how to stay grounded, whose lithe branches have taught me how to be flexible toward change, and whose cascading leaves have taught me how to withstand the sun's most piercing glare. It is my immediate, given family that I want to acknowledge first as the support and love that has made me who I am today. My parents (Monica Chon Ryoo and Jisun Ryoo) have been my greatest role models in life. Thank you, umma, for being the fiercest feminist and most authentic social justice activist that I know. Thank you, appa, for being the most generous person and gentlest spirit that I know. Your examples have guided me along my pathway and continue to inspire me every day. And to my sister (Joan Joonsun Ryoo): you may not realize it, but it was you who taught me how to be fearless. Throughout our lives together, you have always been an adventurer who has exceled at all you attempted, encouraging me to also be daring, but in my own way. Thank you for supporting me, Bats! I could never thank the three of you enough for your eternal love.

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course, thanks Matt Sarno, for fulfilling all my ridiculously high expectations for someone to love and care for Laura!). Mandy Hu, I love you too. (Sorry, couldn't resist the stupid rhyming). You are such an important sister to me. In your presence, I feel free to be my silliest self. Thank you for our random adventures from Monadnock to Half Dome (Oh my god, why did we do that?), from Dolores Park to your living room (Oh my god, that dead horse is reading *the New Yorker*!). Every moment we've shared is a precious jewel to me. Roona Ray, another dear sister, some of my favorite memories have been built with you. Our late night tea-time hangouts in your old Lowell House room (listening to *Blue,* of course) and filming in the empty lot by the coöp are some of my favorite memories. From sharing your mom's baked samosas to the way you taught me to make yogurt, I have always felt loved by you and felt privileged to get to love you. Thanks for over-analyzing everything with me. Ilana Brito, my LonggIsland sister and incredibly brilliant biologist friend, your passionate creativity and loving honesty constantly remind me that great happiness can be found in this world. Thanks for sharing your Nesquik habits with me and baking the best popovers ever and being with me through everything. Lisa Tam, from poke at Magoo's to watching the Pipeline Masters to sharing Selena, I love our sisterhood that was born on O'ahu during our years as teachers. Thanks for brightening my life with your love and incredibly grounded self. (And thanks, Brandon Olander, Chloe, and Colin for all your love and friendship as well. Together with Lisa you make an important part of my chosen family). Bryan Kuwada, one of my dearest chosen brothers, thank you for all the fantastic surf sessions (and with your dad and mom!) as well as the music-sharing, film-watching, face-stuffing, and Ala-Moana-swimming sessions. I still remember the day I met you (the way you were sitting on that bench in the sun outside Jon Osorio's classroom, your long hair gleaming obsidian black, your brow furrowed). I'm certain we've been close friends for many centuries. I look forward to many

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<center>* * *</center>

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Ryoo, J.J. (2011, April). *Algorithms Vs. the 'N-Word': The Advantages and Disadvantages of Writing High School Curricula That Engage Youth Participatory Action Research Under Corporate Funding*. Paper presented at AERA, New Orleans, LA.

Ryoo, J.J. (2010, May). *Listening to the Voices of the Alternative Asian American Press: Transforming Education Today through Gidra of the 1960s-70s*. Paper presented at AERA, Denver, CO.

Ryoo, J.J. & Ho, R. (2009, April). *40 Years Later: UCLA API Student Activists in 2008*. Paper presented at the Association of Asian American Studies Conference, Honolulu, HI.

Ryoo, J.J., Moreno, D., & Crawford, J. (2009, April). *Supporting Students' Spiritual Development for Academic Success*. Paper presented at AERA, San Diego, CA.

Ho, R. & **Ryoo, J.J.** (2008, October). *Still on Strike: the Experiences of API Undergraduate Student Activists at UCLA*. Paper presented at the 40th Anniversary of the SF State College Strike Conference, San Francisco, CA.

Interactions with a Digital Native

It was 8:30pm and time to go to bed.

I was helping my sister with her sixteen-month-old daughter, Ida.

Well…actually, I was "helping" in that I was sitting and watching a fuzzy red puppet on the TV with Ida (as she pointed and screamed "ELBOW! ELBOW! ELBOW!" in a way that inexplicably melted the heart) while my sister washed dishes and did a load of laundry and caught up with some other chores. This is my older sister. She likes to take care of everybody, even if they're at her house trying to take care of her.

"Ida! Time to get ready for bed! Jean, will you go read a book with Ida?" called my sister from the kitchen.

"Of course!" I replied (ever the supporter of reading to children over being couch potatoes with them. I am an educational researcher, don't you know).

"Great!" said my sister, "The iPad's on my desk."

"Huh?"

"I said the…"

"Oh, I heard *what you said…" I interrupted, "but why the iPad?"*

Ida wobbled up onto her pudgy feet, losing all interest in her favorite red "Elbow" at the mention of "iPad."

"She likes the cat story…about Milo…" called my sister.

Ida stared at me with expectant baby eyes that were criminal to ignore. Laughing, I picked her up and, pretending to be an airplane, we flew over to my sister's iPad, grabbed it from her desk, and flew back to the couch together.

Smiling ecstatically and without waiting for me to find the power button (thank goodness, because I wasn't sure where it was), Ida grabbed the iPad and expertly awakened the screen. She unlocked the machine by swiping her finger across the bottom touch-tab, scrolled to the "Apps" icon, and located her favorite Milo "book" from the several options available.

I was shocked.

Not unlike an awkward anthropologist clutching a dog-eared copy of Malinowski's

Argonauts of the Western Pacific, I found myself feeling out of place while interacting with this

"Digital Native" and observing her evening routine that seemed so foreign from my own. As a

voyeur watching a technology indigene with her tool, I was fascinated by Ida's ability to

navigate this new[1] machine. I immediately decided that she was a baby-Einstein because of her

ability to move through numerous windows and achieve a specific goal. Her eyes blazed with the

screen's bluish glow, suggesting the determination and rapid hand-eye coordination of a

computer programmer. How could this child (whose spoken vocabulary only included words like

"*Omma*" and "*Appa*"[2]) so expertly understand the workings of this iPad?

Or did she?

After Ida opened the Milo story app, the screen began to come to life through the

movements of an animated cat as a narrator's voice read the words, "Knock, knock, knock!" that

popped into view. *Alright,* I thought, *This is like watching a cartoon. I understand this…* But

then as we proceeded to "read" about Milo, my perception shifted. Ida began to tap on different

items on the screen: a vase of flowers, a goldfish in a glass bowl, a metronome, etc. I thought

that she was pointing out her appreciation of the drawings, but before I could verbally agree that

I also liked these drawings, the items she tapped came to life. Flowers floated out of a vase, a

goldfish blew bubbles in the water, the metronome ticked a rhythm on the piano.

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[1] Today, as I complete writing this dissertation, Ida is now nearly five years old. Of course, the iPad no
longer seems "new" and some of us may even remember how quickly the first iPad was replaced with the
iPad 2 that was replaced by the iPad 3 that was replaced by the iPad 4 that was replaced by the iPad mini,
etc. And currently there are rumors that the iPad 5 will be released this year, in 2013. The meaning of
"new" is rather short-lived in the world of technological gadgets.
[2] *"Omma"* and *"Appa"* mean "Mommy" and "Daddy" in Korean, respectively.

As an educational researcher who appreciates the multimodal literacies[3] of "Generation Z"[4], I was fascinated with the new ways of "reading" that the app developers had made possible and that my niece highly appreciated in this iPad book. The interactive aspect of the book's background imagery—elements of the picture that had little or nothing to do with the main story or character—became their own side-narratives of the book. "Reading" took on a whole new meaning as images shifted and sounds overlapped, with Ida's sense of touch controlling it all.

Then the experience became chaotic. Before the flowers could complete their floating or the narrator finish his words, Ida would drag her fingers across the screen to return to the previous page. The narrator's voice from the previous page would get interrupted again as she dragged her fingers to the next page. She began to tap at everything, seeking new responses to her touch. Yet not all items were coded for animation, and as she continued switching pages and tapping on items, I began to feel that "reading" was becoming frantic, disjointed, and unfulfilling. I couldn't follow Milo's story, I wasn't sure why we couldn't watch the flowers complete their trajectory out of the vase, and I didn't find the "book" enjoyable anymore.

That's when I came to three important realizations. First of all, I recognized how much I have been socialized to expect the story to be represented in a specific, linear way because the Milo iPad app was supposed to mimic a "book" (and I have been taught that books are supposed

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[3] "Multimodal literacies" are rooted in the idea that a range of communicational, representational, and semiotic modes beyond words and writing—including image, animated movement, tone of voice, gesture, gaze, etc.—impact language and learning. As one might expect, the development of digital technologies has had a dialectical impact on the ways new literacies are currently forming, but multimodal forms of sense-making, communication, and reading the world have always existed. (For detailed descriptions about multimodal literacy and learning, see Jewitt and Kress (2003) or Hull and Nelson (2005) or Vasudevan, Schultz, and Bateman (2010) and work in New Literacy Studies by Lankshear and Knobel (2006) or Gee (2003)).
[4] While there is some contention about how to define who belongs to Generation Z, many agree that it spans our young children through today's high school seniors (Posnick-Goodwin, 2010; Rosen, 2007).

to be read in the order of their page numbers). However, Ida was *exploring* what it meant to "read," learning new ways of reading that I did not grow up practicing.

This led me to my second realization. Ida's ability to navigate this machine did not necessarily mean she was brilliant (although I still believe she is a genius). She did not understand the computer science behind this book app, or even what made this computer different from her other toys. The iPad was simply the tool by which she fulfilled a desire to be amused. The app was what she was experiencing within the limitations of its computer code based on the decisions of its human coders. While Ida may have used some observation and troubleshooting skills to figure out how to turn on the machine and manipulate it, knowing how to *use* the tool vs. knowing how to *create with* the tool are two very different things. I could not definitively say she "understood" this tool simply because she figured out how to use it.

My third realization was that no matter how adept I may be at working with the newest technology or keeping abreast of the most recent computer gadgets, we who call ourselves "adults" can never fully understand what Generation Z experiences growing up in the digital world that was invented during our adult lifetimes. Yet what I *do* know as the "old" person who studies urban schooling and grew up without the internet is that our schools today are faced with a difficult task. Schools must keep up with the world's rapidly evolving computer technology *while also* preparing Generation Z to use this technology for solving future global challenges and filling our country's computing jobs[5] (Hawkins & Schmidt, 2008; Posnick-Goodwin, 2010; Walliker, 2008).

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[5] Computing jobs are the sixth fastest growing occupations in America (Lockard & Wolf, 2012). Furthermore, the U.S. Bureau of Labor Statistics *Occupational Outlook Handbook* (2012) notes: "computer systems design and related services and management, scientific, and technical consulting services—will account for more than half of all new jobs in professional, scientific, and technical services" (U.S. Bureau of Labor Statistics, 2012, par. 30).

Indeed, it is widely acknowledged that knowing how to use computer technology in *creative* ways really does matter.

Considering that these tech-savvy children will have to confront the unknown consequences of climate change, depleting resources, overpopulation, and worldwide hunger, how well are our schools preparing them to yoke their love of technology in order to develop creative solutions to future problems?

Very poorly.

Statement of the Problem

While political, business, and educational conversations now tout "21st century skills[6]" as the key to preparing today's children for becoming the innovators of tomorrow (Pellegrino & Hilton, 2012), the majority of U.S. schools have *not* been preparing our children to be creative problem solvers and critical thinkers with technology-based tools. Only certain students are receiving such a privilege in their highly-resourced schools and thus, only certain people are being prepared to enter technology-based fields in computer science, engineering, science, medicine, and more.

Of course, this is just another variation of a very old melody. Yet, the reasons for this problem are new and complex.

First of all, most people falsely assume that Generation Z children inherently understand *how technology works* without being taught, simply because many children can independently figure out how to *use* technology through tinkering and play. Those of us who grew up without

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[6] According to the National Research Council, "21st century skills" that prepare students to live and work in the digital age are defined as competencies in "cognitive domain, which includes thinking, reasoning, and related skills; the intrapersonal domain, which involves self-management, including the ability to regulate one's behavior and emotions to reach goals; and the interpersonal domain, which involves expressing information to others, as well as interpreting others' messages and responding appropriately" (Pellegrino & Hilton, 2012, p. 2).

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computers often marvel at the agility with which children like my niece can manipulate technology. Yet a child's ability to figure out how to send a text message or Tivo a television program does not directly translate to being a technology prodigy. While my facility in using a cassette tape player amazed my grandmother many years ago, I never exceled at engineering. Rather, *some* children in Generation Z—those who are surrounded by or given access to technology—show comfort with these tools because they quickly learned how to mimic adult uses of tools. But this does not mean that they are engaging such tools in creative ways that negate the need for a computer science education or teacher.

Yet this belief that children automatically know how to use computer technology—and therefore the dangerous belief that children do not need to be *taught* how to use such technology if it is presented to them—has led to the idea that, in order to make sure *all* students (and not just wealthy children who already have computers at home) know how to use computers, we simply have to provide every child with a computer at school. In fact, in an effort to address the problem of the "digital divide" between wealthy families who have computers and economically poor families who do not have computers, various groups of people—from parents to community activists to corporate CEOs—have been fighting to give *every* child access to their own computer.

This brings us to the second issue at hand: the one-laptop-per-student movement will continue to be flawed unless people actively address *what* should be done with these computers once they have been provided. Unless we also counter the various barriers to equitable schooling practices—issues of tracking, pedagogy, etc.—that are impacting children today, computer education will simply serve as yet another means by which the majority of students are denied

opportunities to learn. It isn't only one's access to a computer that matters, but also one's access to quality *education* around computer use.

Thus, notions of the "digital divide" have changed as people realize that decreasing student-to-computer ratios in schools has not resulted in increasing diversity in computer science, engineering, or technology-based fields. The "digital divide" of earlier decades is being amplified not in terms of access to technology, but access to academic supports for *using* such technology.

Indeed, while almost all schools in the U.S. have low student-to-computer ratios, only certain students—our more affluent white male students and certain Asian American male students—are being taught how to use computers to create new programs or design creative uses for technology. Most of our economically poor students and students of color, on the other hand, continue to use computers for primarily basic, word-processing, and non-creative purposes. While only a few students get to use computers to learn the computational thinking skills that will allow them to be producers of new knowledge, the majority are using computers for "drill and kill" or typing programs that will only prepare them to be the consumers of their privileged peers' creations.

The challenge public education faces today is rooted in computer *pedagogy* and student *learning*.

Unfortunately, there is a dearth of research around best practices in computer-based teaching that truly addresses how we can prepare students to be creative users of technology. While many discuss how to develop online teaching seminars or how to use computers to prepare students for standardized tests, few describe how to engage the deeper, critical, computational thinking behind computer science and technology use in high school education.

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Various innovative projects, such as New York's "Quest to Learn" or Chicago's "Digital Youth Network," are building curricula around exciting new media technology with great success in engaging diverse students with new media literacy skills. However, little is understood about the everyday pedagogical practices used by these programs that could be applied specifically to computer science learning in public school spaces. The pressing questions remain: What does effective computer science teaching look like? And how can we prepare diverse students to critically examine the world while using computer science tools?

Overview of the Dissertation Chapters

In an effort to begin addressing these questions, my dissertation examined what effective teaching looked like and what students learned in a mobile phone-based, computer science curriculum called "MyData[7]." MyData was a data analysis unit embedded in an introductory high school computer science course entitled Discovering Computer Science (DCS). DCS was created in collaboration between the Metro City School District and a local Metro City university with the specific purpose of broadening participation in computer science for diverse high school students. The MyData curriculum was unique because it allowed students to use mobile phone technology for researching social issues that impacted their communities. During the 2011-12 school year under study, students used mobile phone app surveys to document personal snacking behaviors and/or neighborhood advertising. After collecting such data, students learned how to analyze the data and present their findings to an audience. In this way, MyData employed hands-on, inquiry-based methods to teach students about how both data and computer science make up the fabric of our lives.

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[7] All names—of cities, organizations, curriculum, programs, schools, teachers, students, etc.—have been changed to protect the confidentiality and anonymity of research participants.

While the MyData curriculum and technological tools were exciting, rather than zooming in only on the novelty of using mobile technology in schools, my study focused primarily on how the curriculum came to life through the shared classroom practices of teachers and students during this unit. I believe that access to technology alone does not provide opportunities for students, but rather student learning is influenced by the ways teachers engage such technology in schools; it is not just the curriculum and tools that change education, but how such a curriculum and tools are taught and experienced in the classroom that are of utmost importance. Thus, my dissertation answered the following research questions regarding three Discovering Computer Science classrooms teaching the MyData curriculum:

1. **How did teachers mediate students' engagement with computational thinking and computer science in Discovering Computer Science classrooms with the MyData curriculum?**
   - What assistance did teachers offer students?
   - How did teachers facilitate learning of computational thinking practices in computer science?
   - How did teachers organize learning in ways that leveraged students' interests in new technology, computational thinking, and computer science?
   - What did effective pedagogy look like in these classrooms?

2. **What did students actually *learn* while participating in MyData research projects?**
   - How did students engage with the MyData project?
   - How, if at all, did students' ideas about technology or computer science change over time?
   - What computational thinking and 21st century skills did students engage in the Discovering Computer Science classrooms?
   - Did students create new knowledge as a result of their uses of technology in these computer science classrooms? If so, in what ways?

In Chapter Two I describe the historical context and provide an overview of the current state of computer and information technology education in U.S. schools. This literature review frames the challenge we face in technology-based pedagogy and student learning and the reasons for asking the research questions above. Outlining the promises of computer technology for high school education, as well as our unfortunate failure at fulfilling such promises, Chapter Two

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provides the backdrop for the innovative, technology-oriented, mobile phone-based curriculum (MyData) that was studied in my dissertation research.

In Chapter Three, I offer a theoretical framework for making sense of teacher practice and student learning in the three dissertation classrooms. The sociocultural perspectives and critical pedagogy described in this chapter influenced my approach to studying teaching and learning in the three schools.

Chapter Four covers my methodology and methods used to answer my research questions. In this chapter, I provide a description of the school contexts and portraits of the participating teachers.

Chapter Five begins to delve into my research findings through this dissertation work. The key pedagogical practices that students defined as "good" teaching and that emerged through classroom observations are illustrated through this chapter.

A more detailed description of the specific ways that teachers organized student learning in their classrooms—which I call "Connected Computer Science Pedagogy" (CCSP)—are described in Chapter Six. The CCSP practices highlighted in Chapter Six show how teachers effectively engaged diverse students in computer science learning by relating academics to students' personal interests and real social issues in their communities while supporting peer-to-peer collaboration.

Chapter Seven identifies yet another pedagogical element that arose as central to effective teaching in the three dissertation classrooms: Humor. This chapter illustrates the ways that all three teachers employed humor as a tool to 1) motivate student learning, 2) make learning less stressful, 3) build classroom community, and 4) mediate positive behaviors in disciplinary situations.

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Chapter Eight addresses my second research question, closely examining what students learned through the MyData curricular unit. I describe how students highly valued new definitions of "data" and felt empowered by the ability to be community researchers who were no longer reliant on outsiders to answer their questions. This chapter offers a close, multimodal analysis of students' final projects, revealing how some students developed important critical thinking and data analysis skills.

Chapter Nine offers concluding remarks regarding this research, its implications, and limitations.

My hope is that this work will be useful to current and future educators who are dedicated to successfully engaging diverse learners with computer science and 21st century skills. Of course, a major challenge to any computer-based pedagogy is the difficulty in keeping abreast of the new technologies that are constantly emerging in our digitized society. Yet, thinking beyond a mere fascination with the technology itself, this dissertation addresses what valuable teaching practices could look like regardless of the tools used to mediate such teaching. By highlighting the shared social practices between teachers and students that supported engaged critical and computational thinking, the pedagogy emphasized as effective throughout this dissertation reveals how teachers can positively impact students learning computer science, even as technology continues to evolve.

My intention is also to show how the data analysis and research skills learned by students through the MyData project underscore the importance of engaging computer science learning within the context of students' real world interests and personal identities as individuals who can positively impact their communities. While the depth of learning varied across students and classrooms, it was significant that students treasured new abilities to be researchers and data

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analysts. Of course, these participating high school students would require much more statistical analysis training in order to pursue futures as researchers, however their appetites for such learning were whetted through the MyData experience.

Yet, as with any innovation throughout the history of humankind, technological change and computer science have the potential to either improve or harm our lives and planet. The ways we engage these innovations truly matter. It is with this idea in mind that I have written this dissertation.

CHAPTER TWO
Computers and Public Schooling: From Technology Haves and Have-nots to
Technology *Education* Haves and Have-nots

Computer Education in the U.S. – From the 1970s to the Present

As Cuban (1986) points out in *Teachers and Machines: The classroom use of technology since 1920*, there has been a pattern in the way schools have dealt with each succession of technological innovation—from film to radio to television—relating to the economic interests of technology developers. First, technology developers conduct their own research to show why their specific form of technology will support learning in schools. Next, schools embrace this technology and pay large sums of money to its developers. However, not all teachers receive the appropriate training to use these tools, nor do they equally value the tools in their classrooms. When no significant impact on student performance is visible, technology developers blame teachers for their resistance, and point fingers at schools for lacking the funds to support the technology. Finally, the technology itself is held responsible for the lack of academic improvement. By this point, a new technological tool is developed, the old one forgotten, and the cycle begins again.

This trend has been no different for computer and information technology in U.S. public schools. Ever since the personal computer was introduced to the world in 1975, schools have been scrambling to get the most recent computers, software, and internet access into their classrooms. For example, between 1981 and 1985, the average number of computers available in schools increased nearly tenfold ("Teachers feel computer gap with students," 1989). By 1987, the number of U.S. schools with one or more computers provided for teaching purposes increased over fivefold (U.S. Congress Office of Technology Assessment, 1988). By 2000, the average U.S. school had one computer for every five students and 98% of all public schools were

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connected to the internet (Cattagni & Farris Westat, 2001). Finally, the most recent counts by the U.S. Department of Education reveal that, as of the 2009 school year, there were 1.7 students per computer[8] across elementary and secondary schools (Gray, Thomas, Lewis, & Tice, 2010). Today, schools are continuing to dedicate a lot of energy toward achieving 1:1 student-to-computer ratios while also focusing on high-speed broadband access, using Web 2.0 tools (e.g., blogs and wikis) with students, having teachers maintain social networking sites, and increasing access to online education opportunities ("Tech Counts 2013," 2013).

The steady increase of computer and information technology in U.S. schools has paralleled high expectations for its impact on improving education and how schools are run. Many have maintained that computer technology would be a "great equalizer" because of the ways its form and function align with educational reform. For example, the internet has the potential to make school learning more applicable to diverse students' lived experiences by bringing the "real world" into the classroom while simultaneously allowing for interdisciplinary subject learning (Berenfeld, 1996, p. 82); computers can encourage teachers to engage more interactive instead of lecture-based learning by using computers for hands-on instruction (Feldman, Konold, & Coulter, 2000); and, most importantly, the internet can promote equity in education because it potentially allows all students to access the same information regardless of race, gender, sexuality, etc. (Berenfeld, 1996; Riel, 1992; Sproull & Kiesler, 1991; Zuboff, 1988).

Indeed, as Joe Roebuck, Apple computer's former director of sales development, predicted in 1982: "Education is the reason people will buy computers" (quoted in Oppenheimer, 2003, p. 10). It did not take long to see that Roebuck was correct. By the early 1980s—as *Time* magazine's May 3, 1982 issue revealed—the belief that computer technology would lead to

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[8] This count included computers that were already available or could be brought into the classroom.

children's academic and economic success had already become so widespread that parents were raising money for school computers by organizing bake sales, car washes, or carnivals while demanding that counselors put their children in computer classes because "it's the wave of the future" (Golden, 1982). According to Cuban (2001), this belief that computers could reform schools was quickly embraced by the American public because of the work of an informal "coalition" (consisting of public officials, corporate executives, policymakers, parents, and vendors) that had been pushing for a school computer revolution since the 1980s. Of course, personal motivations to advocate for computer technology varied significantly among this coalition's members. Some sought profit in selling computer software and equipment, others wanted a "quick-fix" solution to education's historical problems, many believed computers could transform pedagogy for the better, and still others wanted to make sure that low-income students and students of color would not be ignored while the privileged of the world learned how to use the newest technology (Cuban, 2001):

> From many different directions, then, coalition advocates have pressed school boards and superintendents to wire classrooms and purchase new hardware and software, in the belief that if technology were introduced to the classroom, it would be used; and if it were used, it would transform schooling. (Cuban, 2001, p. 12-13)

Today's one-tablet-per-student movement reveals that this belief continues to persist.

Interestingly, the history of numerous state and federal funding measures for building schools' computer-based infrastructures reflects how the U.S. government has literally bought into the perception that technology can "transform" education. At the state level, politicians have been joining with corporations to outfit schools with the latest technology. As early as 1982, Arizona Governor Bruce Babbitt proposed a tax write-off for companies that donated computers to schools, while California Governor Jerry Brown quickly followed suit with a bill that allowed computer companies to decrease their taxes by 25% of the market price for every computer they

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gave to a school (Oppenheimer, 2003). Computer technology corporations have been benefiting

from state measures such as these ever since. Today, funding that allows schools to purchase

new computer technology or software (such as the "Enhancing Education Through Technology"

grant) continues to be offered in states throughout the country on a formula and competitive

basis (for example, see California Department of Education, 2010a).

At the federal level, by 1996, President Clinton offered the Technology Literacy

Challenge Fund that provided $2 billion for five years to schools who would provided computers

and educational software to every student while preparing teachers to teach with technology

(U.S. Department of Education, 1996). President Clinton and Vice President Gore also offered a

discounted "E-rate" to schools with high percentages of low-income students who wanted to

wire their classrooms for the internet (U.S. Department of Education, 1998). More recently, Jim

Shelton, President Obama's assistant deputy secretary for innovation and improvement at the

United States Department of Education and Aneesh Chopra, chief technology officer in the

White House noted that "'Technology is core and essential to the strategies we are using to

reform education'" (quoted in Fletcher, 2009). Reflecting some of the main tenets of his first

presidential election education platform—in which now-President Obama and now-Vice

President Biden expressed how "the information economy is revolutionizing every area of our

lives, but too many schools do not have access to these critical resources" (Obama, 2008)—

President Obama and Secretary of Education Arne Duncan set aside $919 million in State

Educational Technology Grants to bring technology into classrooms (U.S. Department of

Education, 2009).[9]

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[9] It should be noted that while Obama and Duncan have set this funding aside for technology in schools, they continue to force schools to *compete* for *public* funds. Using the same logic as the "Race to the Top" federal funding competition for public schools, states have been mandated to distribute technology on a competitive basis (according to who has the "best" application) and not necessarily based on which

While pressure to build computer technology in schools persists today, and while many continue to believe that technology is the "great equalizer" that will level access to future academic and career opportunities for low-income and wealthy students alike, the results of computer technology proliferation in schools have been less than encouraging. To understand why, let us consider the history of our nation's "digital divide" and its impact on educational reform movements.

(Re)Defining the "Digital Divide" – The Gap Between Technology and Teaching

According to Oppenheimer (2003), the "digital divide" was first referenced in 1983 by International Resource Development, a market-research firm in Norwalk, Connecticut, that reported how increased emphasis on computers in schools did not translate to increased equity for low-income vs. wealthy students: the firm predicted that wealthier students with computers at home would continue to receive unfair advantages over less affluent students without home computers, further deepening the digital divide between the technology "haves" and "have-nots." This digital divide between wealthy and low-income families' access to computers was carefully documented over many years. In 1995, the U.S. Department of Commerce published a report entitled "Falling Through the Net: A Survey of the 'Have-Nots' in Rural and Urban America" that noted how low-income and minority households in central cities and rural areas had the fewest computers and lowest internet access: only 4.5% of rural poor, 7.6% of central city poor, 6.4% of rural African Americans, 10.4% of central city African Americans, and 10.5% of central city Hispanics/Latinos had computers. In contrast, 52.2% of rural wealthy, 58.1% of urban wealthy, 56.4% of central city wealthy, 30.3% of urban Whites, and 39.5% of Asian/Pacific Islanders had computers (U.S. Department of Commerce, 1995). The U.S. Department of

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schools need the technology funding most (such as those schools that do not have time to put together a great application because they are busy attending to the needs of their students).

Commerce's 1998 and 1999 reports revealed that this digital divide actually deepened between those at upper- vs. lower-income levels, and that African Americans and Hispanics/Latinos were even *further* behind Whites in computer ownership and internet access by the late 90s.

Of course, if a student does not have access to a computer and the internet at home or in their local library, s/he will face disadvantages in academic projects that a student with the newest computer and fastest internet access at home does not need to worry about. While one might hope that schools could be the space where students would have equal access to quality computer technology, grave differences regarding computer access in high- vs. low-income schools were documented. By the mid-1980s, not only did wealthier school districts have two times as many computers as poor schools (Levin & Meister, 1984), but these wealthier schools also received better equipment and technical/teacher support (Ascher, 1984; Anderson & Ronnkvist, 1999; Anderson, Welch, & Harris, 1984; Becker & Sterling, 1987; Hayes, 1986).

Recognizing these unfair advantages in resources, advocates for equity in education fought for *all* schools to have the same student-to-computer ratios so that home-based advantages could be leveled in public education spaces. Such was the work of the "coalition" described by Cuban (2001). The coalition's efforts have been successful in terms of student-to-computer ratios that are now nearly equal across all public schools today (Gray et al., 2010). However, a closer look at these schools' *uses* of computer and information technology forces us to recognize that the digital divide experienced by students today is affected by more than just computer or internet access. As noted by Warschauer (2003), "[A] digital divide is marked not only by physical access to computers and connectivity but also by access to the additional resources that allow people to use technology well" (p. 6). In other words, we must consider factors such as general literacy, community resources, social resources, and psychosocial

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variables that might influence students' attitudes toward computers in general (Stanley, 2003; Warschauer, 2003). Furthermore, we must ask the following questions: if students have the newest computers at school, how are teachers preparing those students to use such computers for more than just word processing or typing? Are students in *all* schools being *equally* prepared to be innovators and critical thinkers with technology? What are students actually learning to do with computers in high- vs. low-income schools?

Unfortunately, while the difference between "technology haves and have-nots" is decreasing, the difference between "technology *education* haves and haven-nots" has increased. We do not see equitable access to quality education and the supports necessary for using technology in low-income schools attended primarily by students of color, despite decreasing student-to-computer ratios. Consider, for example, Watt's (1982) description of low-income students who were being taught simply to do what computers told them to do, as compared to wealthier students who were learning how to program the computers themselves. Similarly, Becker (1987) described how, within schools, only students with the highest grades were encouraged to take exciting computer classes, whereas "low-achieving" students (who were primarily low-income students of color) were less likely to take such classes. Other studies describe how privileged students have consistently received encouragement to use computers in more creative ways than other students overall (Apple, 1998; Campbell, 1984).

As Gorski (2005) explains, the digital divide "mirrors patterns of power, privilege, and oppression in the larger society and in the U.S. education system" (p. 37). This reality is visible in the ways teachers have been shown to use computer technology for reinforcing external power hierarchies in the classroom. For example, in one study aimed at increasing African American students' access to computers in elementary school, participating teachers described that they did

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not want their African American students using computers in the classroom because they believed these children would only "'abuse or misuse the computers'" (Moore, Jaffey, Espinosa, & Lodree, 2002, p. 8). In another public school, students of color had access to high quality computers, but these students were only allowed to use these computers for standardized test preparation drills and practice (Pearson, 2002). Indeed, *Education Week*'s 2001 report on technology use in schools described how students in wealthy schools were given opportunities to use technology for real-world, inquiry-based projects; while low-income schools' students were only taught to engage in word processing or web design ("Technology Counts 2001/The New Divides," 2001).

This reality was echoed in Becker's (2000) national survey of computer use by subject area. Becker (2000) showed how students with lower socioeconomic status used computers more than their wealthier peers in math and English classes, but only for drill-type activities. Students with higher socioeconomic status used technology more often in science courses for higher-order thinking activities in simulation and research. Others have similarly shown how wealthier White and Asian American male students are often given more opportunities to use technology for rigorous academic applications, whereas African American and Latina/o students of lower socioeconomic status are encouraged to use new technology only for remedial or vocational uses (Warschauer, 2000; Wenglinsky, 1998). Computers and the science behind technology use are clearly being engaged in different ways with less wealthy students of color, compared to our schools' more privileged youth.

More recent studies further illuminate how opportunities for technology-based learning differ between certain student groups. In a qualitative study of internet use in schools, Schofield and Davidson (2004) revealed how online access was offered only to the most advanced students

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as a privilege or reward, thereby reinforcing the idea that struggling students—those who were English-language learners, had learning disabilities, or faced challenges outside of school that were affecting their educational experiences—did not deserve to use advanced technology. Similarly, in an overcrowded, East Los Angeles high school attended primarily by Latina/o students—a school that received $1 billion through California's 1997 Digital High School legislation to outfit the school's technology program—quality technology was readily available, but advanced computer classes were limited (Margolis, Goode, Holme, & Nao, 2008). The internet publishing course did not introduce students to webpage design unless they took the course for two years, counselors enrolled female students in floristry classes when they preferred to take computer classes, and computer teachers had low expectations for students, stating "'There are some students that just because of their background, they have never been able to— they don't know how to problem solve…they don't have that ability or desire to figure things out or explore'" (Margolis, et al., 2008, p. 40). The situation was no better in a predominantly African American Los Angeles high school with an aerospace program, where one might assume all students would have equal access to higher-order, technology-based education. At this school, students, teachers, and administrators alike saw computer science as a "White and Asian male" field, while teachers' perceptions of Latina/o and African American students did not match the characteristics that these educators believed necessary for success in computer science (Margolis, et al., 2008). Finally, in a wealthy Los Angeles school with high technological resources that enrolled diverse students from different neighborhoods through its math and science magnet, students of color who commuted hours to school were tracked away from taking more challenging computer courses (such as Advanced Placement Computer Science), while their White peers were prepared early on to enroll in such classes without question (Margolis, et al.,

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2008). These studies reveal how teacher, counselor, and administrator perceptions of different student groups affect school sorting mechanisms and have a powerful influence on the computer technology experiences of non-dominant students in public schools.

A recent Pew report (2013) also illustrated significant differences in terms of technology support and training for teachers in high- vs. low-income schools. Of the 2,462 teachers surveyed about digital technology in their schools, 70% of teachers working in the wealthiest schools reported that their schools did a "good job" providing them with resources and support for using digital technology in their classrooms, while only 50% of teachers working in low-income schools agreed (Purcell, Heaps, Buchanan, & Friedrich, 2013). Furthermore, 73% of teachers in high-income schools received formal training for using digital tools, compared to only 60% of teachers in low-income schools (Purcell et al., 2013).

Similarly, a survey of 10,831 teachers attending an online, computer-based professional development revealed that teachers from low-income schools self-reported having lower technical abilities and skills as well as lower levels of access to technology in their schools compared to teachers in high-income schools (Chapman, Masters, & Pedulla, 2010). Valadez and Durán (2007) found that teachers in wealthy California schools had significantly more physical access to computers and the internet, used these resources more creatively for instruction, communicated more with students via email, and engaged more frequently in professional computer-based activities with other teachers. Finally, a comparison of high- and low-resource schools in California revealed how wealthier schools invested more in professional development, hiring full-time technical support personnel, and developing communication norms between teachers, office staff, media specialists, technical staff, and administration that allowed for strong digital networks, compared to less affluent schools that did not have the support networks

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necessary to make technology-based learning thrive (Warschauer, Knobel, & Stone, 2004). In fact, at one wealthy, suburban, majority White school, not only was a full-time media specialist on staff, but twelve teachers were also chosen to be technology facilitators and received extensive in-service training to help others use educational software (Warschauer et al., 2004). In comparison, a low-resource school enrolling a majority of students of color that had a similar student-to-computer ratio as the wealthier school had computer labs that were so poorly managed that internet connections were installed for over five months before any teachers were notified that their students could go online (Warschauer et al., 2004). Indeed, the reality that effective technology use in classrooms is dependent upon the availability of support for teachers has been noted in numerous other studies of school-wide and classroom-based technology implementations (Blomeyer 1991; Collis & Carleer 1992; Diem 1986; Ginsberg & McCormick 1998; Means & Olson 1995; Schofield 1995).

Thus, the fact that students' computer and information technology learning is powerfully affected by more than just the student-to-computer ratio forces us to complicate notions of the digital divide. As stated by Blau (2002):

> Traditionally, people thought that the problem of the divide was solely about the resources that a person had. This assumption led to responses like Newt Gingrich's famous proposal to give a laptop computer to every poor child in the country. Increasingly, however, people involved in the issue have concluded that the problem can't be resolved by simply transferring resources to those without computers. Instead, it looks like solutions need to be modeled on the old-fashioned life preserver: The support needs to be *around* you to keep you afloat. (p. 51)

Children do not become computer science and information technology experts on their own. Indeed, Bolt and Crawford (2000) note: "It is not enough to simply drop a bunch of computers into a classroom and walk away" (p. 30). Without proper pedagogical support, most students will only learn the minimum necessary for using computer technology engaging primarily in remedial

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word processing or uncritical *Google* searches for the first *Wikipedia* definition they can find; and very rarely will a student be able to figure out how the computer works through her or his own individual experimentation toward innovative purposes.

But Why Teach Kids to Use Computers If They Use them All the Time Anyway?

The literature described thus far complicates notions of computer technology as a "great equalizer"—as do current definitions of the digital divide—by revealing how student access to meaningful and creative uses of computer technology is not only limited by access to such technology, but also by the ways teachers engage learning with such technology. Yet how does this affect the children of Generation Z who are already flooding the internet with their *MySpace* and *Facebook* pages? Couldn't one argue that these tech-savvy children do not need to be taught how to use computers because they already have an online presence? Furthermore, couldn't one say that students learn enough about how to use technology through their mobile phones or online gaming activities, making it unnecessary to engage such technology for learning in the classroom?

Certainly, there is no question that many children in Generation Z have a special relationship with new technology that no other generation has ever experienced. However, one must remember that merely *using* such technology is different from *creating* or even *creatively using* such technology. Knowing how to customize one's own *Facebook* page does not equate to building and running a social networking website from scratch. One must have the creativity and desire to build something new with the technologies at hand and understand the technology well enough to innovate from the ground up. Similarly, knowing how to text rapidly or send videos to friends using a mobile phone does not equate to knowing how to develop the software necessary for unique formats of mobile phone texting or video applications. One must have the critical

thinking skills to design new forms of communication and build the applications necessary to make such communication tools function on digital machines. Many members of Generation Z may have shown deep engagement with computer technology, but how many have been taught to use such technology in new or meaningful ways? The literature reviewed earlier in this chapter suggests very few.

But what does it mean to "use technology in new or meaningful ways"? What skills allow students to be innovative or creative with technology?

According to www.code.org's series of videos that received widespread attention at the start of 2013, students need to learn how to program computers in order to innovate and create with technology. This organization has brought together famous people from all U.S. sectors to emphasize that students need to learn programming skills just as much as they need to learn how to read or write. This message was shared through both a video—featuring individuals like Mark Zuckerberg (founder of *Facebook*), will.i.am (from the popular band The Black Eyed Peas), Chris Bosh (NBA All-star for the Miami Heat), Bill Gates (of Microsoft)—as well as through a website with quotes from President Bill Clinton, Vice President Al Gore, actor Ashton Kutcher, Virgin Group entrepreneur Richard Branson, Teach for America's Wendy Kopp, among others. Clearly, individuals with power in various working sectors have come to realize that *all* students need to learn how to code.

But what skills result in excellent coding ability? And isn't there more to computer programming than just learning how to code? What about the *science* behind computer programming? What about the *thinking* behind *computer science*?

In recent years, scholars have carefully outlined the habits of mind and skills that today's youth need—the very same habits of mind and skills that form the foundations of computer

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science and computer programming—in order to move beyond superficial uses of technology toward innovation and creativity with computer-based tools. While many agree that these habits of mind and skills are important for exceling at computer programming, they are rooted in classical "critical thinking" practices upon which *all* academic fields are based. After describing what "critical thinking" looks like according to educational literature, I will briefly outline what scholars have defined as the "computational thinking" and "21st century skills" necessary for all today's children to succeed in school, work, and other areas of life in the digital age. These skills and habits of mind forming the foundations of computer science are the source of creativity and innovation with computer technology.

Critical Thinking, Computational Thinking, and 21st Century Skills

Defining Critical Thinking

In 1990, the American Philosophical Association (APA) published "The Delphi Report" entitled "Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction." This report engaged philosophy, education, social science, and physical science experts in discussing six rounds of questions regarding "critical thinking." As a result of this exercise, these experts defined critical thinking as follows:

> We understand critical thinking [CT] to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. CT is essential as a tool of inquiry. As such, CT is a liberating force in education and a powerful resource in one's personal and civic life. While not synonymous with good thinking, CT is a pervasive and self-rectifying human phenomenon. The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit. (Facione, 1990, p. 2)

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This definition revealed how critical thinking is a "judgment" or problem solving skill used in an "inquiry" process of asking questions and seeking solutions. The "interpretation, analysis, evaluation, and inference" used in critical thinking is described as essential for not only education, but also a student's "personal and civic life." This definition does not stray far from some of the more "classic" descriptions of critical thinking in education. For example, Dewey (1933) discussed the idea of critical thinking through his definition of "reflective thinking" as "[A]ctive, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends" (p. 118). Dewey's description of reflective thinking engages the same idea of "self-regulatory judgment" as a tool for "inquiry" as the scholars describing critical thinking in the Delphi Report. As such, critical thinking requires one to weigh evidence that supports or challenges one's ideas. Similarly, Edward Glaser (1941), co-author of the *Watson-Glaser Critical Thinking Appraisal*, described critical thinking as:

> (1)[A]n attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences, (2) knowledge of the methods of logical inquiry and reasoning, and (3) some skill in applying those methods. Critical thinking calls for a persistent effort to examine any belief or supposed form of knowledge in the light of the evidence that supports it and the further conclusions to which it tends. (p. 5)

One can see that Glaser directly incorporated Dewey's definition of reflective thinking in his definition of critical thinking that involves inquiry methods for examining an idea and determining if the evidence supporting that idea is valid. Interestingly, Glaser emphasizes how critical thinking is an "attitude" toward problem solving.

Elder (2007) explains that critical thinkers also

> work diligently to develop the intellectual virtues of intellectual integrity, intellectual humility, intellectual civility, intellectual empathy, intellectual sense of justice and confidence in reason. They realize that no matter how skilled they are as thinkers, they

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can always improve their reasoning abilities and they will at times fall prey to mistakes in reasoning, human irrationality, prejudices, biases, distortions, uncritically accepted social rules and taboos, self-interest, and vested interest. They strive to improve the world in whatever ways they can and contribute to a more rational, civilized society. (par. 8)

Importantly, this definition of critical thinking moves beyond judgment for the self to problem solving for a larger purpose: improving the world. Here critical thinking is couched within its greater social context and holds a moral purpose. Critical thinking requires one to be reflexive, examining her or his thinking in relation to one's "prejudices, biases, distortions."

<u>Defining Computational Thinking</u>

Interestingly, definitions of computational thinking are based on the same major concepts as critical thinking. Computational thinking includes "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" (Cuny, Snyder, & Wing, unpublished manuscript quoted in Wing, 2011, par. 2). According to the Massachusetts Institute of Technology (MIT) ScratchEd project team (n.d.), computational thinking:

> [I]s not simply a matter of knowing how to use computers. Rather, it means being able to use computational ideas and strategies to understand and describe how things behave and interact. Computational thinking is useful for describing actions and interactions in many different types of systems – cars on a highway, animals in an ecosystem, characters in an adventure game. To develop as computational thinkers, students need to become fluent with a set of computational concepts as well as set of computational practices. (p. 1)

In other words, computational thinking involves using computational concepts and practices to analyze systems and problem solve for all different kinds of contexts. Elaborating on such "computational concepts and practices," the MIT ScratchEd project team explain that computational concepts are useful for describing change over time or processes and include ideas such as sequence (putting actions in a specific order), parallelism (executing different actions at the same time), conditionals (selecting between actions based on whether a certain condition is

true or not), variables (storing data that can be accessed and changed over time), etc. (p. 1). Computational practices, on the other hand, put computational concepts into practice and fall into two categories: *design* practices and *social* practices (MIT ScratchEd Project Team, n.d.). Design practices involve creating computational artifacts (such as games or simulations) and involve things like problem finding (identifying personally-relevant issues and challenges), experimenting (trying out different options), debugging (systematically figuring out what went wrong in a system), or iterating (making revisions and then trying out a sequence over and over again). Social practices involve "collaborating with others on the design and use of computational artifacts" (MIT ScratchEd Project Team, n.d., p. 1) and include practices such as sharing (allowing others to see and use your work), remixing (revising the work of others), or crediting (providing acknowledgement to others when it is due).

Similarly, Wing (2006) explains that "Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" (p. 33). Elaborating on this problem solving process, Wing illustrates that computational thinking involves the following steps: 1) reformulating the problem into one we know how to solve (through reduction, transformation, etc.); 2) thinking recursively about the issue to solve the problem (i.e. interpreting code as data and data as code); 3) applying abstraction and decomposition to the larger task or complex system; 4) choosing the appropriate models of relevant aspects of the problem to make it easier to solve; and 5) considering prevention, protection, and recovery from future error or worst-case scenarios of damage (2006, p. 33-34). Wing also offers everyday examples of what such computational thinking looks like. She explains that a child who chooses what to put in her backpack for the day before going to school is engaging in "prefetching and caching" or a boy who retraces his steps to find his lost

mittens is "backtracking" or an individual choosing which line to stand in at the supermarket is "performance modeling for multi-server systems" (p. 34).

Other definitions of computational thinking reflect the same concepts as those described by Wing and the MIT ScratchEd project team. Phillips (2009) notes that computational thinking involves "moving technology projects beyond 'using' tools and information toward 'creating' tools and information" through manipulating data, using abstractions, etc. (p. 2). The Center for Computational Thinking (2010) at Carnegie Mellon also explains that computational thinking requires using abstraction to understand and solve problems more effectively toward "understanding the consequences of scale, not only for reasons of efficiency but also for economic and social reasons" (par. 6). In this sense, computational thinking moves beyond what is necessary for merely using computers, toward problem solving in larger life contexts in the world with these tools.

These definitions of computational thinking above, all of which focus on computational concepts in both design and social practices as well as problem solving, designing systems, and understanding human behavior, engages the same ideas as definitions of critical thinking. Both critical and computational thinking are used for inquiry processes. Both require purposeful and self-regulatory judgment that requires understanding concepts and practices and applying appropriate methods toward solving a larger problem. Both require interpretation, analysis, and evaluation. These overlapping concepts between the definitions of critical and computational thinking are illustrated in the diagram below:

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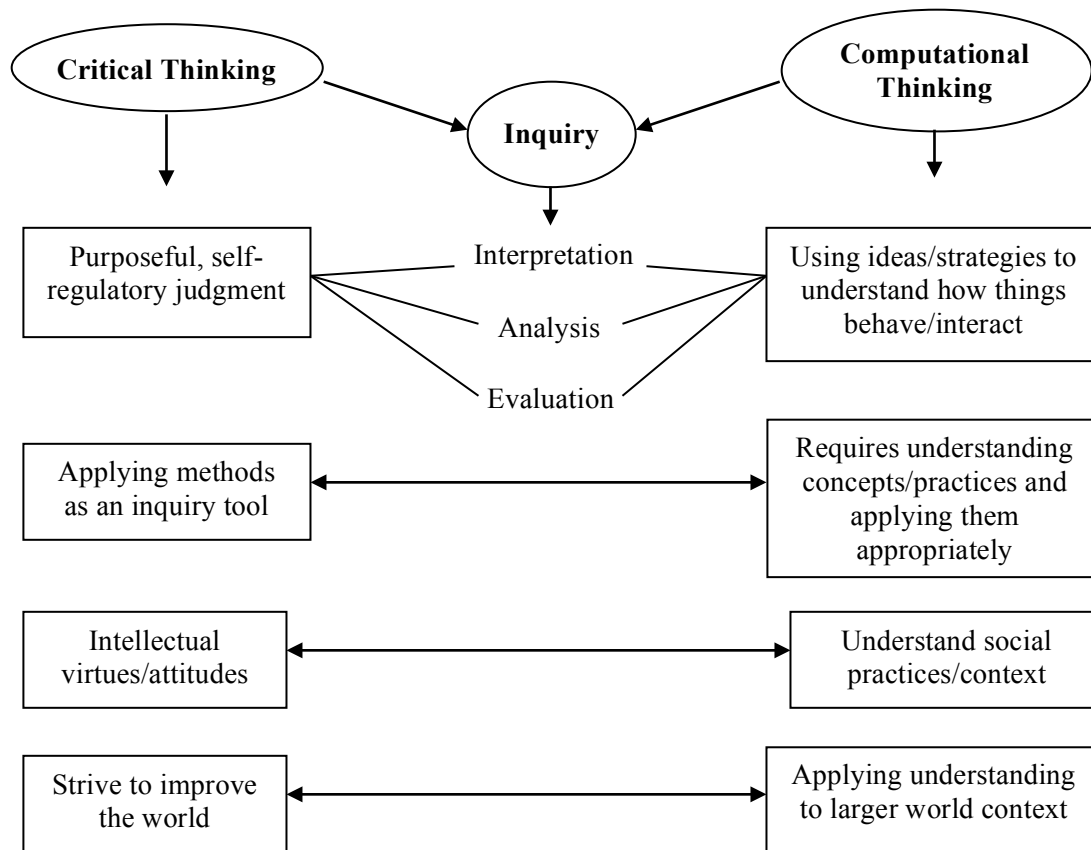
Figure 2.1: *The overlapping concepts of Critical Thinking and Computational Thinking.*

Literature regarding both critical and computational thinking suggests that neither can be divorced from the context of our social world. Both approaches to inquiry are deeply rooted in the everyday human practices that involve interpreting, analyzing, and evaluating daily events or decisions that affect our lives, as well as the problems we must solve to improve the quality of these lives.

Defining 21st Century Skills

Last year, the National Academies Committee on Defining Deeper Learning and 21st Century Skills released a report defining "21st century skills" as outlined by a committee of experts in education, psychology, and economics (Pellegrino & Hilton, 2012). Entitled *Education for Life and Work*, this publication uses the term "competencies" rather than "skills"

to refer both 21st century knowledge *and* skills that include three broad areas: 1) the cognitive domain, or skills related to thinking and reasoning such as critical thinking, analysis, problem solving, etc.; 2) the intrapersonal domain involving self-management and the ability to regulate one's behavior and emotions to reach goals; and 3) the interpersonal domain, an ability to express information to other people and interpret other peoples' messages (Pellegrino & Hilton, 2012).

Reflecting many of the same ideas emphasized in critical thinking and computational thinking, these 21st century skills/competencies have been deemed essential for preparing today's children for the jobs and lives of tomorrow. Interestingly, while the jobs and lives of tomorrow are highly informed by technological innovation, this report on 21st century skills does not focus solely on the importance of being able to use computer-based tools. Rather, this report highlights the types of *thinking* one needs to engage in the world.

In this way, the connections between critical thinking, computational thinking, and 21st century skills seem quite clear. All three are focused on applying problem solving processes—interpreting, analyzing, and evaluating ideas and events—when making decisions and taking action in various social contexts, from school to work to life. Computational thinking and 21st century skills help illuminate why critical thinking skills must be applied to today's learning contexts that are inherently couched in technology-based environments. Moving beyond a mere memorization of coding languages or acquisition of computer literacy with word processing software programs, the critical thinking practices highlighted through computational thinking and 21st century skills provide important learning goals for today's Generation Z youth. They are the skills and competencies teachers must focus on in the current era.

But How Do You Teach Computational Thinking & 21st Century Skills? – Study Rationale

Thus far, we have seen how educational research and policy literature have focused more on providing technological tools rather than on supporting teachers' uses of, and students' equitable learning with these tools. Yet within this sociohistorical context of technology-based education, we also see how politicians, educators, and corporate entities alike are now recognizing that students need to be taught computational thinking and 21st century skills today for occupational and life success tomorrow.

Between these conversations about the importance of the tool and the importance of the skills, little has been discussed regarding *how* to connect tools and skills. There is insufficient understanding of *best teaching practices* that promote learning computational thinking and 21st century skills with technological tools. Exciting new 21st century skills curricula are being developed for both in-school and out-of-school programs, but little can be found in educational research describing the specific teacher actions that support successful implementation of such curricula. Even fewer describe the learning processes of students themselves. Importantly, Ito et al. (2013) has outlined a rich framework for what learning environments should look like that support the development of 21st century skills in what they call "connected learning." Yet, the specific pedagogical practices necessary to build these environments remain unclear. For example, we may understand the taste and texture of a high-quality loaf of bread, but what actions are necessary to achieve that taste and texture? What specific actions can teachers make to support computational thinking and 21st century skills, especially among diverse learners who have had little to no previous exposure to computer science? And what learning results from effective teaching efforts in computer science classrooms?

This dissertation fills this gap in educational research.

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CHAPTER THREE
Theoretical Foundations

Let us return for a moment to the skills and competencies that make up computational thinking and 21st century skills—the learning goals for today's youth in technology-based education. As noted earlier, these skills and competencies cannot be separated from their larger purpose in social world contexts. Consider, for example, Wing's (2006) definition of computational thinking that does not involve only solving problems or designing systems, but *also* "understanding human behavior" (p. 33). As Wing (2006) goes on to explain, computational thinking "is not trying to get humans to think like computers. Computers are dull and boring; humans are clever and imaginative" (p. 35). Learning computational thinking skills does not mean a focus only on creating tools, but instead on designing new concepts that can impact peoples' every day; computational thinking focuses on "Ideas, not artifacts. It's not just the software and hardware artifacts we produce that will be physically present everywhere and touch our lives all the time, it will be the computational concepts we use to approach and solve problems, manage our daily lives, and communicate and interact with other people" (Wing, 2006, p. 35).

Similarly, the National Academies Committee on Defining Deeper learning and 21st Century Skills use terms such as "artistic and cultural appreciation," "personal and social responsibility," "oral and written communication," "active listening," and various other intra- and interpersonal skills that make up 21st century competencies (Pellegrino & Hilton, 2012). As these terms suggest, deeper critical thinking with computer technology in the 21st century involves engagement with the social world.

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The location of the purposes of computational thinking and 21st century skills within social and cultural contexts inherently suggests that learning such competencies should be through sociocultural processes. Teaching these skills divorced from their greater purpose in the social world would render them meaningless. As Warschauer (2003) explains, "ICT [Information and Computer Technology] use is a social practice, involving access to physical artifacts, content, skills, and social support" (p. 46).

As such, sociocultural learning theories serve best for making sense of teaching and learning computational thinking and 21st century skills whose purposes are rooted in the living human world. More specifically, cultural historical activity theory (CH/AT) works particularly well for understanding computer-based education because of its focus on human activities in relation to tools, social structures, and physical environments, all of which are mediated by unique cultural historical factors.

Furthermore, literature regarding computer-based education in the U.S. illuminates how such teaching and learning cannot be understood separately from the sociopolitical forces shaping our public schools. The inequitable computer-based education experiences of students falling along class, race/ethnicity, and gender lines reflect the ways power hierarchies infiltrate learning and teaching in schools. Thus, critical pedagogy proves to be a useful additional lens for thinking about teaching and learning in computer science classrooms.

In this chapter, I will describe how sociocultural theories (and CH/AT in particular) as well as critical pedagogy inform this study's approach to understanding teaching and learning of computational thinking and 21st century skills in secondary computer science classrooms.

Cultural Historical Activity Theory (CH/AT) and Sociocultural Theories of Learning

What is CH/AT?

Cultural-historical activity theory (CH/AT) draws from the work of L.S. Vygotsky, A.R. Luria, and A.N. Leont'ev who, in turn, drew from Hegel and Marx to inform psychology in their time. CH/AT examines the complex, feedback relationships between thought and action, theory and practice, psychological functions and culture[10]. While followers of Vygotsky, Luria, and Leont'ev may differ in their beliefs about whether the human mind is best understood by looking at "mediated action" (the ways culture, in the form of tools and signs, mediates human thought) as the most important, basic unit of analysis (Wertsch, del Rio, & Alvarez, 1995; Zinchenko, 1985), or whether human psychological development is best understood by looking at human "activity" (and the setting in which such action takes place) as the unit of analysis (Engeström, 1987; Kaptelinin, 1996), CH/AT theorists refuse an "either/or" approach to these scholars' work and recognize that *both* cultural mediation *and* activity are important to comprehending how the human mind affects human practices and how such practices, in turn, affect the mind (Cole & Engeström, 2007). In this way, CH/AT theorists approach their research and work by thinking of "mediated action in context" as the basic unit of analysis (Wertsch, 1991; Cole & Engeström, 2007).

Cole and Engeström (2007) provide an outline of the theoretical principles that privilege "mediated action in context" as a unit of analysis for understanding the human mind. These CH/AT principles can be understood as follows:

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[10] Culture here is defined as a living, dynamic concept moving beyond the confines of race/ethnicity to include all the daily practices, tools, signs, forms of communication, etc. that people engage within sociohistorical contexts. Accordingly, cultural practice shifts depending on social context and power relations.

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1) *Human life is mediated through the use of artifacts*. CH/AT recognizes that humans

   modify material objects that, in turn, regulate human actions/interactions with the world

   and each other. As explained by Luria (1928), artifacts incorporated into human action

   not only "radically change his conditions of existence, they even react on him in that they

   affect a change in him and his psychic condition" (p. 493) (Quoted in Cole & Engeström,

   2007, p. 485).

2) *Activity is an essential unit of analysis*. Embracing the cultural-historical approach

   engaged by both Hegel and Marx, CH/AT recognizes how human psychological

   functions must be historically situated—considered within the context of their action—in

   order to understand them. In this sense, the human mind is best comprehended in the

   context of "activity systems." Activity systems can be defined as a complex whole in

   which an individual or sub-group directs its/their activity toward an object (raw material

   or problem space) that is transformed toward a specific outcome (with the help of

   physical, symbolic, external, and internal mediating instruments/tools) within the context

   of a community (who share the same general object) and according to a division of labor

   (that involves the division of tasks between members of that community based on power

   and status) according to both explicit and implicit rules within the activity system

   (Engeström, 1987).

3) *Culture is central to human life*. CH/AT embraces the ways that culture—in the form of

   tools, signs, rituals, etc.—mediate human activity. Culture is accumulated in a group's

   social history over time and is a living entity capable of shifting and changing.

4) *Adoption of a genetic perspective*. CH/AT recognizes that, in order to understand current

   phenomena, one must study the history of such phenomena. While Vygotsky (1978)

terms this as the "genetic" origins of human phenomena, he does not mean that one must look at human DNA to understand human culture, action, or thought, but rather that one must look to their historic roots and, therefore, study such phenomena over an appropriate period of time to see their history and progression.

5) *Higher psychological functions have social origins*. CH/AT theorists recognize that the way humans learn new thoughts and incorporate new behaviors into their daily lives is through the social sphere. As Vygotsky (1978) explains when describing how young children learn: "Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first *between* people (*interpsychological*), and then *inside* the child (*intrapscyhological*)" (p. 56-7).

6) *There are ethical dimensions to research incorporating CH/AT that require researcher sensitivity and responsibility to others*. Recognizing that understanding human mind/action through CH/AT involves deep engagement with people in their home communities that may differ from the home communities of CH/AT researchers themselves, CH/AT theorists must remember to put the physical/mental health, needs, and desires of those they work with before their own research agendas. Exploration into the historical roots, social contexts, and local meanings of peoples' community-based thought/action over time can put both researchers and communities under study in vulnerable and challenging positions due to power imbalances and varying politics.

(Cole & Engeström, 2007, p. 485-488)

Thus, from the CH/AT perspective, human minds are mediated by peoples' interactions—with each other and the non-human world—through culture. Culture itself (as embodied in artifacts, signs, etc.) is "socially inherited" and has a specific historical context due to previous

generations of humans participating with each other and the surrounding world through such artifacts, signs, actions, etc., that acquired value over time (Cole & Levitin, 2000, p. 69). Culture, as noted earlier, is not limited to the confines of race or ethnicity and is dynamic in nature. Artifacts, in turn, have both material and symbolic meaning and, while shaped by humans for specific, "pre-scribed" goals, such tools simultaneously influence the ways we think and interiorize culture (Cole & Levitin, 2000, p. 70). Thus, in order to understand human mental life, one must examine the different practices or forms of activities that people engage over time or, in other words, their "joint-mediated activity" that is culturally organized and historically situated (Cole & Levitin, 2000).

Yet, how do these ideas relate to human learning?

CH/AT provides a valuable theory for understanding learning and human thought because it examines how the mind works in its cultural, historical, and socially-rooted context. Through CH/AT, learning is examined in relation to, and is *never* divorced from, the student's lived context. As noted by Luria (1981), "in order to explain the highly complex forms of human consciousness one must go beyond the human organism" and include the "external conditions of life" in society (p. 25). Vygotsky (1978) explains that human learning—as seen in young children—occurs on two planes: first on the social and then on the psychological. He describes this through the example of a child who learns how to attain objects beyond his reach by pointing. A child reaching for a bottle might throw his hand towards that bottle in an effort to grasp it. The parent, watching the child, might recognize he wants the bottle because he is reaching for it, and while pointing at the bottle ask, "do you want the *bottle*?" Then, the parent might give the desired bottle to the child. This critical moment in which the adult reacts to the child becomes a learning point for the infant who recognizes that "pointing becomes a gesture

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for others. The child's unsuccessful attempt engenders a reaction not from the object he seeks but *from another person,*" such that the grasping movement acquires a new meaning "from an object-oriented movement it becomes a movement aimed at another person, a means of establishing relations" (Vygotsky, 1978, p. 56). This example illustrates not only how learning is a socially-mediated activity, but also how internalization of new meaning can occur from the social to the psychological for children and adults alike. Furthermore, this example shows how learning is culturally situated: not all humans interpret or use pointing in the same way.

The basic structure of human consciousness in relation to socially-based learning of new behaviors—involving an active subject (S), object (O), and cultural medium (M)—can be depicted as a triangle (described by Vygotsky (1929) as "the cultural method of behavior" (Cole & Levitin, 2000)).
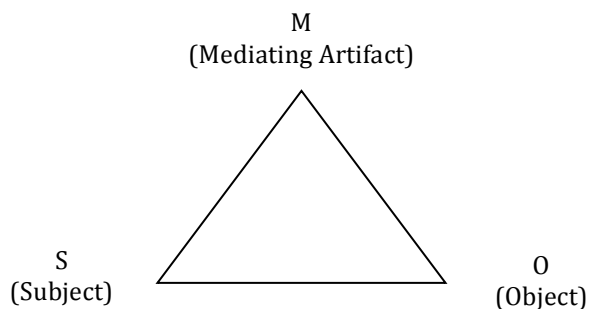
Figure 3.1: Basic meditational triangle according to Vygotsky.

In the above diagram, the base of the triangle—directly connecting subject (S) and Object (O)—represents the "natural" (phylogenetically controlled) processes that are *not* mediated by culture. The other sides of the triangle represent the ways in which the subject and object are linked through mediation in the cultural world or through cultural artifacts. These lines show how cultural mediation alters how subject links to object, response links to stimulus, and so on.

Recognizing that this is not a perfect representation of human thinking due to its simplistic form and static look (and it is clear that human consciousness is neither simple nor

static), Cole (1996) suggests that in place of this more inert triangle, one might draw a gap between the "natural" and "cultural" lines to represent the ways that people reconcile sometimes discordant information coming from these different sources of information. In this way, consciousness can be understood as the process of reconciliation between our different ways of understanding the world—both natural/unmediated and culturally mediated—over time through human action (Cole, 1996). In the triangle below, time is included in the unit of analysis as shown by the difference between the Subject at time "n" (as St_n) and the Subject at a later time (St_{n+1}). The Subject's need for active, cognitive resolution of discrepant ideas between mediated and unmediated thought is illustrated inside the oval encircling the space between O_{sm} (Object mediated by stimulus means) and O_n (Object unmediated and existing under natural means).

M
(Mediating Artifact)

O_{sm}

St_{n+1}
(Subject at time "n+1")

St_n
(Subject at time "n")

O_n
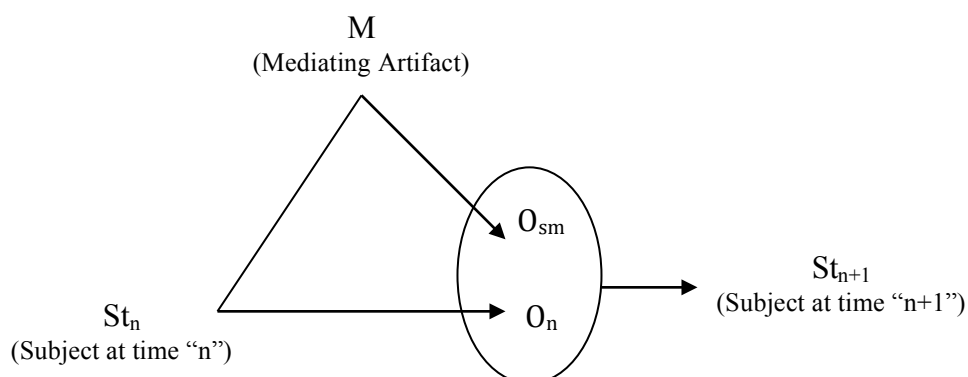
Figure 3.2: Cole & Levitin's (2000) adapted meditational triangle.

Thus, learning can be said to occur in the space encircling O_{sm} and O_n as humans reconcile what they know without and with mediating artifacts in the process of gaining consciousness toward a new state of being (St_{n+1}). In the context of Vygotsky's example of a child learning to point, this triangle can represent the child's learning process according to the following: the child began as St_n when he reached for the bottle. The action of reaching for the bottle out of natural desire could be considered the line connecting St_n to O_n. However, the parent recognizing the child's desire and mediating his reach for the bottle by also pointing and then giving the bottle to the

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child can be considered M (the mediating artifact or cultural influence on the situation) such that the child learns that the parent's action (pointing to the object desired) creates a reaction from others towards O_{sm}. In the process of making sense of the reaching for the object (O_n) and engendering a reaction from the parent by pointing to the object (O_{sm}), the child negotiates meaning in the oval space between O_n and O_{sm} until he reaches a new consciousness of meaning-making out of the act of pointing, thus reaching a new state of being represented as the Subject at St_{n+1}.

Engeström (1987) complicates this triangle representation of human consciousness even further by representing the idea in relation to activity systems. In other words, recognizing that humans function in the context of cultural rules, community organizations/institutions, etc., the following triangle illustrates human consciousness relating to the ways we learn or make sense of the world within larger social contexts:
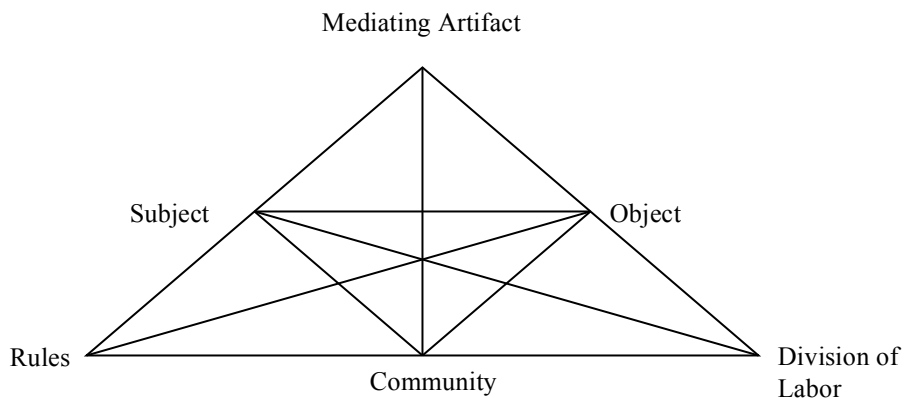
Figure 3.3: _Engeström's (1987) meditational triangle elaborating on the various social contexts impacting mediation of human sense-making and consciousness._

In this rendition of the basic mediational triangle illustrating human consciousness, Engeström brings forward the ways that other people (within our communities), social rules (as influenced by the cultural world within our communities), and the division of labor between the individual "subject" and others (as defined by institutions created through culture and community)

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influence our thinking and learning. All aspects of this triangle are interconnected and linked, showing how all aspects of an activity system—visible in this triangle—influence human thought. As noted by Cole & Engeström (1993), "Consequently, activity systems are best viewed as complex formations in which equilibrium is an exception and tensions, disturbances, and local innovations are the rule and the engine of change" (p. 8). Again, using Vygotsky's pointing example, one can see that the child's learning about how pointing at an object can elicit a response from another person can be understood through Engeström's mediational triangle: the "subject" reaches for the bottle, but through the parent's mediation (represented as the child's learning "community"), the subject learns a new "object," which is that pointing can make another person recognize what you want and bring it to you. However, this interaction between child and parent is influenced by social "rules" about how parents should attend to their children, as well as a socially constructed "division of labor" between parent and child that defines how the two should interact in their familial community. Furthermore, culture is the "mediating artifact" defining those rules and the division of labor between child (subject) and parent (community) that leads to learning about the interpretation of pointing.

Taking into account this dynamic relationship between the cultural-historical world and human consciousness, Cole and Levitin (2000) note:

> It is by being incorporated in the meaningful, culturally organized, coordinated, joint activities of a human community that human infants come to acquire higher psychological functions. This cannot be accomplished without the active, exploratory, information-seeking activity of the child, nor without the tolerance, if not willingness, of the community to facilitate this process. (p. 80)

In other words, since human thought and consciousness are powerfully interconnected to human social systems, historical context, and culture, we, as a community, must be particularly careful about how we organize learning for students of all ages. More specifically, within the classroom

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space, teachers' organization of learning should take into account the cultural-historical, social context of each student's consciousness that is uniquely positioned, constantly changing, and powerfully influenced by rules and the division of labor of schools.

<u>The Zone of Proximal Development (ZPD)</u>

To such an end, Vygotsky (1978) introduces the concept of the "Zone of Proximal Development" (ZPD) that helps clarify the relationship between development and learning in relation to the socio-historical context and activity systems in which such development and learning take place. In defining this concept, Vygotsky begins by challenging three major ideas about learning and development that were popular during his time (and continue to be popular today). First, Vygotsky pushes against Piaget's notion that mental development is always a prerequisite for learning. Instead of believing that development or maturation is only a precondition for learning, but never the result of it, Vygotsky (1978) considers how the two may actually be interconnected such that learning influences psychological development just as much as mental development prepares one for new learning. Secondly, Vygotsky (1978) challenges the belief that learning is the same as development, that Pavlov demonstrated through his experiments with dogs taught to salivate on reflex at the sound of a bell. Such "reflex" theories of learning and development suggest that education is based on acquired habits of conduct or behavior, and thus development is the same as learning all possible responses to a situation until such responses substitute one's innate response. Vygotsky argues that learning is much more complex than simply acquiring reflex-based reactions to stimuli. Thirdly, Vygotsky challenges Koffka's theory in which learning and development are mutually dependent. Koffka and others suggest that "the process of maturation prepares and makes possible a specific process of learning. The learning process then stimulates and pushes forward the maturation process"

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(Vygotsky, 1978, p. 81). In this concept of learning and development, development is always larger than learning itself, in that "Once a child has learned to perform an operation, he thus assimilates some structural principle whose sphere of application is other than just the operations of the type on whose basis the principle was assimilated…learning and development do not coincide" (Vygotsky, 1978, p. 83-4). Vygotsky disagrees with the notion that development is larger than learning and that the two are separate.

Rejecting these three theoretical positions on learning and development, Vygotsky presents the concept of the ZPD by first asking the question: When does a child's learning begin? Drawing from Marx's use of the genetic method that emphasizes the importance of historical context, Vygotsky considers how a child's in-school learning has a previous history that began out of school; students come to school with previously learned knowledge and skills, such that "Learning and development are interrelated from the child's very first day of life" (Vygotsky, 1978, p. 84). One is not larger than the other, one is not the precondition for the other, and the two do not have to happen separately. Children begin learning as they develop in social settings long before they enter the classroom. The ZPD takes these ideas into account and provides a way for educators to organize learning toward a student's potential development, rather than according to the mere abilities this student has already attained.

Oftentimes, learning is measured by giving students paper-based tests that they must complete silently and alone. Students are not given examinations that can be done in groups or with assistance. Such tests are supposed to illustrate the mental functions of a child's *completed* developmental cycles and it is assumed that the work children can do on their own indicates their full mental abilities. Yet, learning does not happen in a vacuum and if we offer a student leading questions or begin to show them how a problem might be solved, they can take up the ideas and

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solve the rest of the problem on their own. Not all students are capable of solving problems with assistance, however, and this is where Vygostky's ZPD helps illustrate the more subtle differences in learning, development, and human thinking.

Vygotsky (1978) explains the ZPD through an example of two ten-year-old children who, when given a test to do on their own, were both considered to be at an eight-year-old level of mental development. Vygotsky gave these two children a twelve-year-old level task that neither of them could solve on their own, and then offered assistance with solving the task at hand. With assistance, one student was able to solve the problem while the other could not finish it. After several, similar test trials with children that illustrated their different levels of mental ability with assistance, Vygostky began to wonder: are these two children really at the same stage of mental development if one, with assistance, can solve a problem and the other, with the same assistance, cannot solve that problem?

Vygotsky clarifies that we cannot fully understand a child's mental ability and developmental stage through observing what s/he can do on her/his own. Instead, more can be comprehended about a child's learning and development when we consider the social context of her/his learning and the ways social interaction—through assistance—might mediate what we understand of the child's development and, subsequently, their learning. This subtlety in learning and development is what the ZPD defines.

The ZPD is "*the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers*" (Vygotsky, 1978, p. 86). The ZPD helps one understand what a child's mind is reaching towards, as well as its historical context, defining:

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those functions that have not yet matured but are in the process of maturation, functions that will mature tomorrow but are currently in an embryonic state. These functions could be termed the "buds" or "flowers" of development rather than the "fruits" of development. The actual developmental level characterizes mental development retrospectively, while the zone of proximal development characterizes mental development prospectively. (Vygotsky, 1978, p. 86-7)

Thus, the ZPD takes into account the cultural-historical context of a student's thinking through that student's "actual development," while considering how that student's thinking might change through mediation in the activity system of classroom community, rules, and division of labor toward a new, potential state of development.

The CH/AT approach to human consciousness and the ZPD become powerful tools not only for understanding how students think and develop, but also for organizing learning in the classroom. If we organize learning around students' potential development instead of around their actual development (or what they already know), then, through assistance, mediation, and support from more expert others (teachers and student-peers alike), we can urge students toward a higher consciousness and the deeper learning they are capable of achieving. As stated by Vygostky (1956):

Instruction is good only when it proceeds ahead of development, when it awakens and rouses to life those functions which are in the process of maturing or in the zone of proximal development. It is in this way that instruction plays an extremely important role in development. (p. 278)

In this sense, the ZPD is not a static step ladder of learning for students, but a dynamic representation of the constant learning and growing toward a future state of being that individuals are capable of achieving with mediation/support.

The concept of the ZPD has become particularly popular in the educational world for its potential use in organizing learning for diverse students. However, as Palinscar (1998) notes, the ZPD is "probably one of the most used and least understood constructs to appear in

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contemporary educational literature" (p. 370). Indeed, Griffin and Cole (1984) caution the ways educational researchers have applied the concept of ZPD to in-school learning. They note how "next-step" versions of the ZPD that focus on providing students with environments that have just the right amount of difference between students' prior achievements and present demands (Hunt, 1961)—such that effective teaching is defined as providing the "next step" and ineffective teaching goes too far beyond the student's current ability—are too static in their stepwise progression and too adult-centered in their organization because they do not take into account the ways students may learn through changing responsibility for certain steps over time rather than through the presence or absence of such steps (Griffin & Cole, 1984). Similarly, Griffin & Cole (1984) challenge the ways people equate "scaffolding"—introduced by Bruner and Wood in the 1970s as "adult tutorial interventions [that] should be inversely related to the child's level of task competence"—to the ZPD. These researchers note that the scaffold metaphor fails to address a student's creativity because the tendency is to assume that the child's development should be pushed toward the adult's achieved wisdom and cannot stray on a different path. The scaffold concept is too stiff and adult-oriented to align neatly with the concept of ZPD (Griffin & Cole, 1984).

Indeed, the future growth and state of being for the student should not be a mere copy of the teacher's skill set or state of being. The ZPD offers breathing room for students, with mediation and support, to develop in their own ways while acquiring the skill set or knowledge necessary for such creative development. As Griffin and Cole (1984) note, the adult/teacher role should vary from activity to activity in such a way that social organization and activities provide a space in which a child can develop new and creative ways of thinking. This also makes room for the rich diversity of perspectives that different individuals bring into the classroom. Griffin

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and Cole (1984) reference Emerson (1983), who notes that a ZPD "is a dialogue between the child and his future; it is not a dialogue between the child and an adult's past" (p. 62). Learning organized through the ZPD engages students in appropriating new tools toward making meaning of the world in new ways.

<u>The Importance of Play and Tinkering in Learning – The ZPD and Creativity</u>

Vygotsky (1978) emphasizes how play is one of the most important ways children learn and develop. Play creates a self-imposed ZPD:

> In play a child always behaves beyond his average age, above his daily behavior; in play it is as though he were a head taller than himself. As in the focus of a magnifying glass, play contains all developmental tendencies in a condensed form and is itself a major source of development. (p. 102)

In this sense, while a child may enjoy play, it serves a greater purpose in developing creativity. Smolucha (1992) outlines Vygotsky's theorization of this creativity-development process: 1) children learn to create and manipulate signs and symbols through play; 2) this play becomes internalized as fantasy and imagination; 3) imagination gains higher mental function as an individual develops inner speech; 4) concept-based thinking joins with imagination in adolescence; and 5) this can build into artistic or scientific creativity in adulthood (see Moran & John-Steiner, 2003).

The value of incorporating play into learning environments has been documented in after-school programs such as Michael Cole's Fifth Dimension (Cole, 2006; Laboratory of Comparative Human Cognition, 1983, 1989) or Kris Gutiérrez's Las Redes program (Gutiérrez et al., 1999a, 1999b; Gutiérrez, 2002). In these interventions, learning is arranged through children's play with computer-based games while engaging with an adult or more-expert peer in a co-constructed ZPD (see Blanton, Greene, & Cole, 2000). Students learn to appropriate new

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game-play strategies, problem solve, and communicate through creative play in these after-school spaces.

The ZPD constructed through play situations opens space for new learning to be creative and imaginative in problem-solving situations. Expanding one's creativity through play improves one's ability to abstract oneself from a concrete situation, consider various responses, and choose an action accordingly. Those with limited creativity have difficulty imagining new solution to various problems or challenges. Providing space for play allows children to build those creativity skills toward future problem solving. Such creativity is particularly important for computational thinking and 21st century competencies.

Real Life Applications: Sociocultural Theory Comes To Life

Various programs beyond Fifth Dimension and Las Redes have applied sociocultural and CH/AT theories to organizing and studying learning. Below are some of the key ideas that have grown out of such projects.

Funds of Knowledge

Recognizing that people acquire and engage valuable cognitive skills through *both* in school and outside of school, the Funds of Knowledge Project (González, Moll, & Amanti, 2005; Moll, Amanti, Neff, & González, 1992) sought to redefine students' out-of-school expertise as a valuable resource for in-school learning, instead of a negative crutch to be looked down upon or ignored. "Funds of knowledge" are defined as the social and intellectual resources for learning that students gain at home or in their local communities (González, Moll, & Amanti, 2005). In this project, Teachers became researchers of their own classrooms and their students' out-of-school lives through home visits, then based lesson plans on the relationship between students' everyday and academic experiences. The effects of this project on teacher practice were

phenomenal. One teacher reported how efforts to learn from her student's personal interests improved the student's in-class behavior and academic work while inspiring ideas for a successful classroom project that benefited all students (Messing, 2005). A special education teacher described how incorporating the funds of knowledge of the "toughest kid in the class," who had anger management issues and run-ins with the police, resulted in huge improvements in the student's behavior such that he both became a leader in the classroom and was "mainstreamed" into traditional classrooms the following year (Messing, 2005, p. 189). By challenging deficit notions of students' cultural knowledge and reframing such knowledge as a resource, this project pushes literacy scholars to consider how cultural mediation of knowledge can be used as a tool for learning to read and write in more meaningful ways that connect to students' lived experiences.

Cultural Modeling

Carol D. Lee's (1995, 1997, 2000, 2001, 2007) Cultural Modeling approach—that "seeks not only to address ways of understanding cultural displays of knowledge in everyday contexts, but also to structure ways of participating that enhance identity development and therefore engagement and persistence" (Lee, 2007, p. 27)—uses students' outside-of-school uses of language (in this case, African American Vernacular English) as a tool for intellectual reasoning in the dominant English classroom. Lee (2007) explains that Cultural Modeling "is a framework for the design of learning environments that examines what youth know from everyday settings to support specific subject matter learning" (p. 15). Lee (2001) builds on students' uses of historically developed language practices to engage student-generated questions about complex literary texts, mediate learning across lessons, develop new critical reading norms, and build the ability to create intertextual links. For example, when analyzing the book *Rattlebone* (Claire,

1994), Lee (2001) takes up students' use of "signifying" (Smitherman, 2000)—an African American Vernacular English rhetorical practice often interpreted as "off task" behavior in the classroom—as a tool for making claims about the text and supporting those claims with evidence from the text. Lee (2001) explains: "African American English Vernacular offers a fertile bridge for scaffolding literary response, rather than a deficit to be overcome" (p. 101) so that students can be socialized into academic discourse and practices using familiar tools that make canonical texts more accessible. Through Cultural Modeling, students improved their reading and writing skills in essay and discussion contexts. By highlighting the everyday tools students already use, and then engaging such tools for making sense of canonical texts, students can develop new ways of relating to language and literacy practices.

Hybridity as a Resource

Drawing from similar beliefs that students' home language and literacy practices learned outside of school can be seen as a resource for learning other literacy or in-school, academic practices, Gutiérrez, Baquedano-López, and Tejeda (1999b) explore how we can reframe ideas of diversity in schools by embracing "hybridity" and "hybrid language practices." Drawing from other scholars' work around hybridity—particularly in postcolonial studies regarding borderlands (Anzaldúa, 1987; Arteaga, 1994; Becquer & Gatti, 1991; Bhabha, 1994, etc.)—Gutiérrez et al. (1999b) note that hybridity is commonly found in urban classroom settings in which local cultural knowledge and linguistic registers are negotiated by students trying to make sense of their own identities in relation to prevailing norms about learning and cultural practices. Usually, hybridity—particularly linguistic hybridity—is suppressed and devalued in classroom settings, as visible in California's English-only initiatives to ban bilingual education (Proposition 227). However, linguistic hybridity can often form a collaborative resource for learning by

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increasing opportunities for dialogue and student engagement (Gutiérrez, Baquedano-López, Alvarez, & Chiu, 1999a). In fact, when considering linguistic practices in what Gutiérrez, et al. (1999a) define as the "third space"—which is a space outside of the teacher's directly mediated space where hybridity and diversity intersect in potentially productive conflict—students' language use and conversation that may challenge the teacher's directives can actually serve to support literacy learning on multiple registers. By embracing students' hybrid language and literacy practices that fall outside the traditional practices of English speaking in classrooms, teachers can build upon tensions inherently residing between dominant and nondominant languages toward deeper thinking skills and multiliteracy engagement.

<u>CH/AT as a Tool for Understanding Teaching and Learning in the MyData Curriculum</u>

CH/AT becomes a useful tool for thinking about how to understand teaching and learning of computational thinking and 21st century skills in relation to the purposes of these learning goals for creative problem solving in human social contexts (as previously described in Chapter Two). CH/AT is also valuable for examining the implementation of the MyData curriculum under study in this dissertation research. This is because the MyData curriculum focuses on teaching students to make sense of their own data within the sociocultural contexts of their lived realities. This curriculum takes into account not only students' communities, but also power hierarchies, divisions of labor, and social rules impacting students' engagement with their data collected and analyzed using mobile phone and computer tools. This computer science unit draws on students' funds of knowledge while encouraging creative thinking as students tinker with the data they collect. Through this process, students learn the interpretation, analysis, and evaluation central to inquiry processes that were highlighted in both computational thinking and 21st century skills (see Figure 2.1 in Chapter Two). Critical thinking, computational thinking, 21st

century skills, and the creativity required to employ these competencies when collecting, analyzing, and presenting data all overlay well with the tenets of CH/AT.

Within the MyData curriculum that teaches students how to do their own community-based research on topics that are meaningful to them through the medium of mobile phones and computer-based analysis, CH/AT proves a useful tool for making sense of how teachers and students engage learning about data collection and representation because the curriculum highlights computer literacy in ways that reflect many of the CH/AT principles described by Cole & Engeström (2007) earlier in this chapter.

Addressing Power and Politics in Public High School Classrooms – Critical Pedagogy

Recognizing that public education is not only socio-historically situated—as theorized through a CH/AT lens—but also entrenched in the institutionalized power hierarchies of political struggle (visible in class oppression, sexism, racism, heterosexism, etc.) that influence and organize our daily lives, I find that critical pedagogy proves a useful, additional lens to use when thinking about teaching and learning practices in high schools.

Interestingly, CH/AT and critical pedagogy both find their historical roots from the same parental source of knowledge and thought. Both the grandfathers of CH/AT (Vygotsky, Luria, Leont'ev, etc.) as well as the initial pioneers of critical pedagogy (McLaren, Giroux, Apple, etc.) drew their ideas from the work of Karl Marx. The early creators of CH/AT drew from Marx's *Theses on Feuerbach* that, among many things, questioned positivist notions that humans can be purely objective by stating that human sensuousness is born within the human mind and not through the human's activity or practice (1845/1967). Drawing from Marx's ideas, Vygotsky challenged 1920s psychology dominated by psychoanalysis and behaviorism by bringing forth the concept of artifact-mediated and object-oriented action as sources of human consciousness

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and thought (Vygotsky, 1978; University of Helsinki, 2003). In this way, Vygostky used Marx's theories to explain how humans do not merely react to the environment through a biologically engrained response mechanism, but through their own agency that is mediated by cultural means through tools and signs in historical context (University of Helsinki, 2003). Similarly, Leont'ev (1981) used Marx's concept of labor to explain human object-oriented activity, showing how humans relate to the world through their relationships with other people "which means that labor appears from the very beginning as a process mediated by tools (in the broad sense) and at the same time mediated socially" (p. 208). For the field of psychology, such perspectives of human learning and thought were revolutionary because they challenged the belief that humans are controlled by their subconscious mind as well as the belief that humans are dictated by their genetic makeup. CH/AT theorists' illumination of the relationship between activity systems, tools, culture, and the human mind was liberatory in the ways it highlighted individual agency, challenged "deficit" beliefs that one's racial or ethnic makeup determines one's intelligence, and supported the idea that, with the proper support system and understanding of a person's socio-historical context, people can constantly learn and grow.

Critical pedagogy was also born of Marxist critique (McLaren, 2005). As an emancipatory philosophy committed to empowering non-dominant students, critical pedagogy urges educators to 1) recognize the political nature of traditional schooling based on economic power structures that work against the interests of those students who are most politically and economically vulnerable in society (Giroux, 1997; McLaren, 1998; Shor, 1992); 2) understand how educational reform must involve partnerships with communities that incorporate community funds of knowledge into school curricula (Duncan-Andrade & Morrell, 2008; Moll, Amanti, Neff, & Gonzalez, 1992; Morrell, 2008; Valenzuela, 1999); 3) move away from banking

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education and rote memorization practices toward an education that supports critical thinking skills (Freire, 1970); 4) challenge the teacher-student hierarchy by recognizing the ways teachers can also be students (Freire, 1970; McLaren, 1998, 2003, 2005); 5) encourage student agency by providing students with the support and knowledge necessary to understand the world and change it in positive ways (Morrell, 2008; Freire, 1970; Freire & Macedo, 1987); and 6) support a dialectical perspective that embraces critical praxis—uniting theory and practice—as a tool for envisioning social change through engaged inquiry, reflection, dialogue, and collective action (Duncan-Andrade & Morrell, 2008; Freire, 1970; Morrell, 2008). Thus, critical pedagogy importantly asks questions about *whose* knowledge is valued and *why*.

In many ways, these tenets of critical pedagogy overlap with those of CH/AT. For example, critical pedagogy's respect for community-based partnerships relates to CH/AT's emphasis on engaging students' funds of knowledge and embracing their home-based cultures/practices toward collaboration in learning. Also, both critical pedagogy and CH/AT challenge the ways banking education is used in schools today, recognizing that learning needs to be socio-historically situated and relatable to students' lived experiences. Furthermore, both CH/AT and critical pedagogy scholars recognize the ways that teacher and student roles are in constant flux in a healthy classroom environment. Finally, both theories emphasize the importance of praxis toward positive social change.

It should be noted, however, that CH/AT and critical pedagogy differ in what they offer to the public education conversation. CH/AT provides a rich theory of learning and development that many works in critical pedagogy lack. Yet critical pedagogy meticulously analyzes the relationships between our capitalist economy, politics, and public schooling that are not always addressed in CH/AT. CH/AT examines how teachers "mediate" student learning, whereas

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critical pedagogy examines how "pedagogy" can be used to empower students against the oppressive "status quo." While both theories provide rich descriptions of effective teacher practice, one is focused on student learning and engagement while the other is focused on student liberation and agency.

While CH/AT offers an invaluable perspective on shared practices between teachers and students in the public school classroom, critical pedagogy proves useful here as a tool for deeply analyzing the relationship between schools and social reproduction in a way that is slightly different from CH/AT. By defining teaching and learning as inherently *political* practices, critical pedagogy provides the tools necessary to think about how forms of knowledge often serve to reproduce social inequalities through education (Apple, 1990; Giroux, 1997). Critical pedagogy urges educators to take up their own political roles within the system while positioning themselves as individuals who willingly "struggle for a qualitatively better life for all through the construction of a society based on non-exploitative relations and social justice" (McLaren, 1998, p. 172).

By viewing school as a liberatory space where teachers can work alongside students for positive social change, critical pedagogy could be particularly salient as a lens for examining how teachers and students work together on the MyData community-based research projects designed for informing and improving students' lives. Since this curriculum values student knowledge and supports student-driven research for improving the health and quality of life in their home communities through their own perspectives, critical pedagogy becomes a relevant means of interpreting the ways politics and power are analyzed (or fail to be analyzed) in the computer science classroom.

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CHAPTER FOUR
Methodology and Methods:
An Interpretive Critical Case Study of Three Computer Science Classrooms

"People who look through keyholes are apt to get the idea that most things are keyhole shaped." (Anonymous)

Introduction

One's approach to educational research is just as important as what one reveals through such research; depending on the methods used, a different story may be told. A scientist who examines beehive-building practices by observing the outer structure of the hive will provide a different account of its construction compared to a scientist who observes the behaviors of the worker bees as they build the hive themselves. Similarly, a researcher who describes a classroom using students' test scores alone will have a different narrative of learning than a researcher who talks to the students about what they did during the school year. Research methods powerfully shape what one has the opportunity to see.

Of course, methods are shaped by one's philosophical perspective and knowledge base. As noted by Kelly (2006), "observations, choices of procedures, and inferences made from data are dependent on the beliefs one holds about the world" (p. 34). Research methods involve more than just a set of procedures. Methods are rooted in one's *methodology*—the theoretical assumptions underlying one's study (Erickson, 1986; Genishi & Glupczynski, 2006). Thus, as described in Chapter Three, the methods I outline here are informed by both my sociocultural understanding of classrooms as living communities in which teachers and students engage in shared activities that are uniquely positioned in time and space, as well as my critical pedagogical understanding of classrooms as influenced by the politics of power hierarchies defined predominantly by class, race, and gender, I approach this educational research with the

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belief that humans are complex beings who, through cultural practices that are historically situated, share learned systems of meaning-making but, as individuals, may interpret similar objects or behaviors in different ways. In this sense, I define teaching, learning, and student engagement as socially negotiated processes that emerge through co-participation in culturally situated practices when using historical tools and resources (Davis, 2003; Lee, 2001).

Seeking to understand such socially negotiated processes taking place in classrooms—commonly defined as "pedagogy" and "student learning"—as well as what these social actions mean to the actors involved in them at the time they take place, I employed what Erickson (1986) describes as an interpretive participant observational approach to this work. More specifically, I conducted an interpretive critical case study of three high school Discovering Computer Science (DCS) classrooms that implemented the MyData mobile phone-based curriculum.

In this chapter, I begin by providing an overview of my methodological approaches—interpretive participant observation and critical ethnography—as well as my reasons for choosing these philosophical foundations for my work. After outlining the unit of analysis used to examine my dissertation research questions, I describe the context of my work (i.e., portraits of the three schools and their teachers, as well as the history and purpose of the Discovering Computer Science course and the MyData curricular unit embedded in the course). This is followed by a summary of the methods used to make sense of teacher practice and student learning in these computer science classrooms.

Methodology

Interpretive Participant Observation

Qualitative researchers recognize that the ways we understand and make meaning of the world are socially constructed through the interactions we have with one another in that world

(Merriam, 2002). An *interpretative* qualitative researcher takes this a step further by privileging the "*immediate and local meanings of actions*, as defined from the actors' point of view" (Erickson, 1986, p. 119). Interpretive qualitative research focuses on a daily practice, carefully documents the details of that practice, and seeks to identify what that practice means to its participants and observers (Merriam 2002; Erickson, 1998). Thus, the central research questions of interpretive qualitative research "concern issues that are neither obvious nor trivial. They concern issues of human choice and meaning, and in that sense they concern issues of improvement in educational practice" (Erickson, 1986, p. 122). Erickson (1986) explains that interpretive qualitative approaches to educational research are particularly important for five reasons:

1) It is difficult to see key patterns in our daily actions as we perform them because they become so routine that they seem "invisible";

2) Educational research is in need of better quality documentation of concrete details of human practice;

3) While behaviors in different educational contexts may seem similar, such similarity is misleading because these behaviors may carry different local meanings in different communities. We need to consider what those local meanings are;

4) We could benefit from a comparative understanding of different social settings in education; and

5) We should use comparisons of varying social settings in order to challenge the assumption that diverse people should all follow one, standard, operating procedure in schools. (p. 121)

Thus, a strong interpretive research study pushes us to be conscious of, and to scrutinize those practices that have become so familiar to us that they are often overlooked as common sense (Page, 1990; Geertz, 1973). I believe this interpretive qualitative approach is valuable when considering daily teacher practice and student engagement with educators and non-dominant youth whose personal perspectives and experiences have often been marginalized or ignored in conversations about teaching and learning.

Critical Ethnography

In addition to interpretive participant observation, I draw from critical ethnography to inform my research approach. Critical ethnography: 1) challenges positivist notions of pure researcher objectivity by emphasizing the social construction of human knowledge as well as the need for researcher reflexivity toward more ethical research methods; 2) recognizes how power relationships affect the structure and agency of institutions, researchers, and the subjects of research, and therefore the way data are collected and analyzed; and 3) focuses on the dialectic as a tool for rethinking how we conduct and use research with the goal of achieving liberatory and transformative praxis. Recognizing how research can potentially work against or reinforce systems of class, race, gender, and sexual oppression, critical ethnographic approaches illuminate how educational research can function as social criticism while also addressing how facts are never separate from the values and ideologies in which they are formed (Barton, 2001; Harding 1986; Kincheloe & McLaren, 1994).

Immanuel Kant (1996), one of critical theory's earliest influences, believed that "objectivity" and knowledge of "truth" were impossible to achieve because humans were submerged in a world where popular dogma masqueraded as "truth." The only way to distinguish between truth and dogma would therefore involve dissecting one's epistemological base through

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a critical process of self-examination, in which one questions the knowledge one has come to accept as "truth" by considering how one acquired such knowledge and from where it originated (Kant, 1788/1993; Morrell, 2008). In *The German Ideology*, Marx and Engels incorporate this challenge of recognizing "objectivity" and "knowing" into their own critical theory of consciousness. Contesting the idea that human consciousness is separate from experiences of the material world, as well as the idea that all consciousness is simply a sensory projection of the material world, Marx and Engels (1846/1976) explain how there is a dialectical relationship between consciousness and material practice, human objectivity and subjectivity (Allman, 2007). Drawing from Hegel's (1979) dialectic, Marx & Engels (1846/1976) note how consciousness is influenced by human sensuous activity that is simultaneously influenced by the historical and cultural contexts of human thought and practice such that only praxis between human thought and sensuous activity can reveal deeper consciousness. Critical ethnography addresses this challenge of weighing "objectivity" against "knowing" by rigorously examining the biases of the researcher her/himself. As Henry Giroux (1997) states, "'methodological correctness' does not provide a guarantee of truth nor does it raise the fundamental question of why a theory functions in a given way under specific historical conditions to serve some interests and not others" (p. 42). Thus critical ethnography embodies "self-conscious criticism":

> [S]elf-conscious in the sense that researchers try to become aware of the ideological imperatives and epistemological presuppositions that inform their research as well as their own subjective, intersubjective, and normative reference claims. Thus critical researchers enter into an investigation with their assumptions on the table, so no one is confused concerning the epistemological and political baggage they bring with them to the research site. (Kincheloe & McLaren, 1994, p. 140)

Similar to interpretive qualitative research, critical ethnographic methods help me understand how information acquired through data collection and analysis involves a process of interpretation based on human definitions of experience that are culturally and historically

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situated (Giroux, 1983,1997; Kincheloe & McLaren, 1994; McLaren, 1986; Weiler, 1988). Critical ethnographers recognize how the values, histories, and practices of both researchers and the communities in which they do their research position them as consumers and producers of subjective knowledge (Atwater, 1996).

Since data analysis is conditioned by the researcher's own ideological beliefs and empirical data "cannot be treated as simple irrefutable facts" but instead "represent hidden assumptions," the critical researcher must "dig out and expose" such "hidden assumptions" (Kincheloe & McLaren, 1994, p. 144). This involves self-reflection and what Kincheloe and McLaren (1994) refer to as "humility" that "should not be self-deprecating, nor should it involve the silencing of the researcher's voice; research humility implies a sense of the unpredictability of the sociopolitical microcosm and the capriciousness of the consequences of inquiry" (p. 151). The researcher must be willing to be "vulnerable" such that "the exposure of the self who is also a spectator…take[s] us somewhere we couldn't otherwise get to" (Behar, 1996, p. 14). Kleinsasser (2000) similarly notes that researcher reflexivity allows us to "blur distinctions between the personal and the theoretical rather than hold them separate or ignore one at the expense of the other" (p. 156). In this sense, reflexivity allows the researcher to reconsider her/his ethics, examining both the process and product of her/his work. Kleinsasser (2000) writes: "Ethics cannot be separated from epistemology and, to this end, reflexivity on ethics has everything to do with good data" (p. 157). As part of the reflexive project, critical ethnographers must be willing to use their work and writing as a space to both learn and "unlearn" their personal ideologies, making their "thinking visible" (Kleinsasser, 2000, p. 158). Research reflexivity sits at the heart of my methodology.

Through this reflexive project, I attempt to conduct research that "move[s] beyond assimilated experience…[and] expose[s] the way ideology constrains the desire for self-direction, and the effort to confront the way power reproduces itself in the construction of human consciousness" (Kincheloe & McLaren, 1994, p. 152). Since our public schools are riddled with inequalities based on class, race, gender, sexuality, and more, we as researchers must be continuously sensitive to the ways that these inequalities have evolved and are influencing what we study and how we study it in schools. Researchers embracing critical ethnography recognize the existing power inequalities between themselves and those with whom they work, but also the potential for changing such power relations for the better of all involved. In this way, critical ethnography strives to be a liberatory practice for both researcher and "researched" as all participants "becom[e] increasingly critically conscious of their situations in the world and the impact this has on relationships and knowledge construction" (Lather, 1991, p. 295). While power structures may be oppressive forces in school communities, the critical ethnographer can actively help reshape those power structures so that people traditionally disengaged through research practices find new agency through the research itself.

But how is this possible? Through an engagement with dialectical thinking towards transformative praxis. Marx shows how to use dialectical thinking (drawn from Hegel) in his analyses of capitalism when illustrating the relationship between the preconditions of current events and the present, and when explaining the "essence" of capital versus how it is experienced in our everyday lives (Allman, 2007; Marx, 1865/1981; Marx, 1867/1976; Marx, 1878/1978). The Frankfurt School built upon Marx's analyses of capitalism to show how dialectical thinking

> transform[s] the concepts which it brings, as it were, from outside into those which the object has of itself, into what the object, left to itself, seeks to be, and confront it with what it is. It must dissolve the rigidity of the temporally and spatially fired object into a

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field of tension of the possible and the real: each one in order to exist, is dependent upon the other (Adorno, Albert, Dahrendorf, Habermas, Pilot, & Popper, 1976, p. 69)

Dialectical thought pushes me to compare what I *think* I see through my specific knowledge base with how others may view that work differently from their own epistemological grounding. This process opens space to consider how practices and events would or could be in a different, better world. Dialectical thinking allows a researcher to "analyze the reality of the social object against its possibilities" (Giroux, 1997, p. 42). This, in turn, pushes the researcher to consider the challenges of bridging thought and practice while recognizing how human knowledge and activity, together, are both products and forces shaping the world.

Critical ethnography works well with Erickson's (1986) description of the constant comparative approach in interpretive participant observation that puts multiple observations, views, and ideas in comparison with one another to better clarify local meanings. Indeed, marrying interpretive qualitative research and critical ethnography allowed me to be cautious about the types of conclusions I drew from data collected and analyzed while examining classroom interactions in school spaces. During the analysis process, these two methodologies helped me put disparate and parallel interpretations of teacher and student classroom practice into dialogue with one another, allowing me to achieve a richer understanding of the schools I observed.

Research Design - Unit of Analysis and Research Questions

Using the philosophical grounding of interpretive qualitative research and critical ethnography, I conducted a case study of three classrooms. Case studies that are detailed examinations of singular settings, subjects, or events (Bogdan & Biklin, 2003) can be useful because they allow one to gain deeper understandings of local experiences that other research designs do not offer. Case studies delve deeply into "process rather than outcomes, in context

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rather than a specific variable, in discovery rather than confirmation" (Merriam, 2001, p. 19) so that researchers can provide rich descriptions of a learning event that might provide insight into similar practices in different contexts.

My aim was to enhance our understanding of the teaching and learning of computational thinking and 21st century skills when students conducted their own research using mobile phone technology. For such purposes, I chose three school sites (specifically for the strength of their teachers despite their low standardized test score rankings) with the intention of describing common practices in effective teaching and learning with the MyData curriculum in spaces rarely recognized for their educational successes.

Teachers' and students' "shared practices"—as they engaged in data analysis and computational thinking through the mobile phone-based research projects in the MyData curriculum—served as my primary unit of analysis. In other words, my dissertation data collection and analysis honed in on: 1) the types of assistance that teachers offered students and that students offered to one another throughout the course of the unit; 2) the kinds of relationships that developed between classroom community members; 3) the ways students and teachers engaged cultural tools such as language, mobile phones, and computers, to make sense of the students' research projects; and 4) the quality of interaction between classroom community members.

Employing this unit of analysis as the main lens for understanding the three dissertation classrooms, I sought to answer the following questions:

1. **How did teachers mediate students' engagement with computational thinking and computer science in Discovering Computer Science classrooms with the MyData curriculum?**
   - What assistance did teachers offer students?
   - How did teachers facilitate learning of computational thinking practices in computer science?

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- How did teachers organize learning in ways that leveraged students' interests in new technology, computational thinking, and computer science?
- What did effective pedagogy look like in these classrooms?

2. What did students actually *learn* while participating in MyData research projects?
- How did students engage with the MyData project?
- How, if at all, did students' ideas about technology or computer science change over time?
- What computational thinking and 21st century skills did students engage in the Discovering Computer Science classrooms?
- Did students create new knowledge as a result of their uses of technology in these computer science classrooms? If so, in what ways?

These questions evolved over the course of my dissertation research as my definitions of teacher practice and student learning deepened. Such shifts in my research questions reflect the nature of qualitative research and the process of learning something new (Erickson, 1998). Before I began observing these classrooms, my first question regarding teacher practice was focused more on how teachers used technology to mediate student learning. "Learning" was vaguely defined. Through my experiences in the classroom, however, I began to recognize that "learning" in computer science involved more than just technology use, but also the appropriation of computational thinking and 21st century skills (i.e., the problem solving, inquiry process, and critical thinking practices described in Chapter Two). Furthermore, within the context of an introductory computer science course, it came to light that a large part of teaching computer science involved making this field accessible to diverse students. Among other things, "teaching" encompassed capturing the interest of students so that they gained the confidence and motivation to persist in seeking answers to challenging computational thinking problems. For diverse learners, many of whom were intimidated by computer science or entered the classroom thinking that the course would be boring, a key element of teacher practice was effectively engaging students in learning new ideas or skills. Thus, my first research question shifted in focus from

technology use to the ways teachers mediated student engagement in computational thinking and 21st century skills while implementing the MyData curriculum.

My second research question also became more nuanced, moving away from a curiosity about how students' appropriated technological tools toward an examination of the skills and concepts learned. As the school year progressed, I realized that the mobile phones were exciting tools to bring into the classroom, but remained only that: tools. Of greater interest were the ideas and competencies students acquired when using these tools (not merely how students engaged with the tools themselves). As I wondered whether the mobile phones were even necessary for students to learn the data analysis skills of the MyData curriculum, new lines of inquiry emerged around the nature of student learning in computer science. Thus, my second research question shifted to examining what students learned (if anything) in relation to computational thinking, 21st century skills, and data analysis in computer science.

Research Context – Metro City Unified School Sites and Participants

This dissertation research took place in three different secondary classrooms at Presidential High School[11], City High School, and Midtown High School located in Metro City—a large urban area on the west coast of the U.S.

Metro City is a sprawling metropolis of contradictions. Dry, chaparral-covered mountains and parched desert sand marking the northern and eastern edges of Metro City stand in stark contrast to the well-watered, green lawns and turquoise swimming pools of its wealthiest inhabitants. Soothing ocean waves and warm beaches along Metro City's westernmost boundary exist opposite stop-and-go traffic and expanses of hot asphalt roads that choke even the heartiest of weeds. By day, some of the U.S.'s most lucrative businesses—movie and advertising

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[11] All names—of the participating city, school district, schools, teachers, curriculum, etc.—have been replaced with pseudonyms to protect research participant privacy.

industries—find their lifelines in Metro City on the streets where homeless people lay down their cardboard beds to sleep every night. Brand new Rolls Royces can be found on the same highway as rusting Datsun pick-up trucks. Fast food chains can be found in the same neighborhood as gourmet food trucks. Adults can be found playing "Guitar Hero" in local bars while famous rock bands perform on stages next door. For some, this city is a hedonist's dream come true where vacation memories are made. Yet, for many others this city represents a daily struggle to survive.

Despite the incredible wealth of many of Metro City's major industries, its government, and public schools in particular, are struggling to make ends meet. The Metro City Unified School District (MCUSD) is one of the largest in the U.S.—stretching over diverse but racially and economically segregated neighborhoods—and is also viewed as one of the most disorganized. MCUSD superintendents are constantly quitting, being fired, and replaced. The mayor (who has no teaching or school administration experience) has attempted to take over MCUSD schools. Charter school organizations have tried to take over neighborhood MCUSD traditional schools. Almost all schools are facing a financial crisis with budget cuts that have resulted in teacher layoffs and unpaid furlough days, resulting in fewer instructional hours for students in school. In comparison to other public schools in the state, MCUSD schools are suffering: 13% have severe shortages of qualified teachers and 52% are overcrowded according to the state's definition (UCLA Institute for Democracy, Education, and Access (IDEA), 2010). Compared to the nation, MCUSD schools do not have enough quality resources: 100% of schools in the district have student-to-teacher ratios that are higher than the national average, 81% have student-to-counselor ratios that are higher than the national average, and 51% of MCUSD schools have more than 20% of their college preparatory courses taught by unqualified teachers (UCLA IDEA, 2010). Such public school conditions reveal yet another contradiction

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about Metro City: while MCUSD public schools suffer, many of Metro City's wealthy, private schools attended by Metro City's most affluent children have been flourishing and can boast 100% graduation and college-going rates for their students.

It is within this landscape that my three public school research sites—Presidential High School, City High School, and Midtown High School—do their best to thrive.

The Participating High Schools

Presidential High School

Presidential High School is located in a primarily Latino community near downtown Metro City. This school enrolled 1,624 students in grades 9-12 during the 2011-12 school year. The student population was 90.6% Hispanic/Latino, 7.4% African American, 0.1% Asian American, and 0.2% American Indian (Ed-Data, 2013a)[12]. Over 34% of students enrolled at Presidential High were English Language Learners (with the majority of these English Language Learners speaking Spanish at home) and, according to the school's Academic Performance Index (API)[13] 2012 Growth Report, over 90% of students qualified for free/reduced price meals (Ed-Data, 2013a). The teacher population, while not reflecting the same ethnic make-up of Presidential High's students, was fairly diverse: 37.6% of teachers were Hispanic/Latino, 28% were White, 21.5% were African American, and 7.5% were Asian American (Ed-Data, 2013a).

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[12] My focus on demographic information here is not intended to squeeze students, teachers, and their school communities within the one-dimensional boxes of race/ethnicity and class. I would like to emphasize that people are much more than what their gender, annual income, or skin color may define. However, I provide these more traditional descriptions of the school sites—student ethnic/racial makeup, test scores, etc.—in order to offer as much context as possible based on the perspectives of various, reputable information sources (e.g., school district websites, university-based research organizations, local newspapers). I urge readers to take caution in their interpretations of these demographic descriptors that do not encompass teachers' dedication to their students or students' excitement to learn that I observed at all three dissertation schools.

[13] The Academic Performance Index (API) assigned to schools is based on each school's results from the Standardized Testing and Reporting (STAR) program annual examinations. Under the federal No Child Left Behind Act (NCLB), from 2003 forward, the API is also used for evaluating schools' Adequate Yearly Progress (AYP). API growth is used as a measure of whether or not schools have met their score growth goals.

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Academically, Presidential High was in year five of Program Improvement[14] status because it did *not* meet its 2012 Adequate Yearly Progress (AYP)[15] targets (Ed-Data, 2013a). This school's API base was measured at 546 out of 1,000, which was quite low in comparison to the statewide target base measure of 740 (Ed-Data, 2013a). For every 100 9th graders that enrolled in this school, twenty-seven graduated four years after, and twelve passed courses required for admission into state universities (UCLA IDEA, 2011a).

Presidential High sits in a neighborhood sandwiched between Metro City's downtown industrial district and an area known for its gang-related violence. This neighborhood has been struggling through America's economic downturn with an unemployment rate of 19.5% as of Fall 2010 in comparison to the state average of 12.5% (UCLA IDEA, 2011a). According to Metro City Planning Data estimates, the median household income was $31,559 (in 2008 dollars), with high numbers of foreign-born residents (52.7%) and single parent households (26.3%) for the city (*Los Angeles Times*, 2013a).

Among the three dissertation schools, Presidential High seemed to be undergoing the worst pressures from state budget cuts that negatively impacted the school culture. During the 2011-12 school year, several teachers lost their jobs—including my focal dissertation teacher, Mr. Torres, and a History teacher across the hall who won a national Teacher of the Year award—based only on seniority rather than teacher quality. School administration did little to nothing to assist these educators in fighting for their positions or in finding new jobs at other

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[14] Program Improvement (PI) status is assigned to schools that, for two consecutive years, failed to meet their Adequate Yearly Progress (AYP) in the same content area (i.e. English/language arts or mathematics) school-wide or for any numerically significant subgroup, or on the same indicator school-wide. While under PI status, schools must comply with federally mandated interventions and services.

[15] Adequate Yearly Progress (AYP) must be achieved by schools under the federal NCLB and is based primarily on student performance and participation. In order to meet AYP, the percent of students in each subgroup scoring "proficient" or above in English/language arts and mathematics on standardized tests must meet or exceed target percentages, the percent of students in each subgroup taking such tests must meet or exceed 95%, and schools must improve their graduation rates (Ed-Data, 2013a).

schools, leaving these educators overwhelmed with the responsibilities of scheduling and preparing for hearings with the school board while simultaneously prepping for their classes and other school duties (e.g., grant applications, coaching, after school teaching). Furthermore, since funding was affected by attendance and the neighborhood experienced incidences of violence, it was not uncommon to find the school principal and several police officers standing outside the main entrance and, after the morning bell rang, a long line of tardy students would accumulate. Bathrooms were often locked and inaccessible to students while adult monitors could be found roaming the hallways during class. On my second visit to the school, one such monitor even yelled at me to "go to class" until she finally realized that I was an adult visitor to the school. While we eventually came to joke about this later as this hallway monitor and I became more friendly with one another, her reaction to my presence in the hallway reflected the kind of treatment that students experienced at the school on a regular basis.

Despite the economic challenges facing the community and the policing experienced by students within the school, the neighborhood members surrounding the school and the students and teachers seemed bright and lively. During my commute toward the school, I would often see children in uniform walking together toward their schools, some holding hands and running or jumping. Parents could be seen walking with their children, hoisting small, brightly colored backpacks over their shoulders. Adults and children alike would stop at street corners to buy food from a man selling breakfast out of a shopping cart. On Presidential High's campus, teenagers shouted and laughed together, strolling through the main courtyard or up and down stairwells with smiles on their faces. Students would give high-fives to certain teachers and staff members or holler greetings and jokes at each other down the hallways. Smiles were easily exchanged between myself and the students as I walked through the halls.

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Presidential High's computer science classroom was filled with older PC desktops, one or two of which could often be found in disrepair. However, Mr. Torres actively fixed problems on the desktops on his own and, whenever he could not fix a networking or hardware problem, someone would be hired to attend to the problem. While Mr. Torres usually had the extra responsibility of repairing his own computers, his students never had to share computers due to technical difficulties because of his attentiveness to maintaining these tools. Students would only share computers if it was necessary for their collaborative projects.

City High School

City High, located on the edges of a historically Korean community and the border of Metro's entertainment industry center, is a large school just like Presidential High, enrolling 1,959 students during the 2011-12 school year. Of those students, 76.5% were Hispanic/Latino, 11.7% were African American, 6.3% were Asian American, 1.4% were Filipino, 3% were White, and 0.9% were American Indian (Ed-Data, 2013b). 25.5% of students were English Language Learners speaking diverse languages at home (including Spanish, Korean, Filipino or Tagalog, French, Arabic, and more) (Ed-Data, 2013b). 88.8% of enrolled students qualified for free/reduced price meals (Ed-Data, 2013b). City High's teachers were majority White (43.9%), but also included 17.5% Hispanic/Latinos, 15.8% African Americans, 9.6% Asian Americans, and 9.6% Filipinos (Ed-Data, 2013b). Similar to Presidential High, City High was also in its fifth year of Program Improvement Status, with an API base measured at 637 out of 1,000 (Ed-Data, 2013b). For every 100 9th graders that enrolled in this school, twenty-seven graduated four years after and seven passed courses required for admission into state universities (UCLA IDEA, 2011b).

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City High is situated in a dynamic neighborhood that is considered quite diverse for Metro City, with nearly equal numbers of Asian Americans, African Americans, and Latinos—at approximately 20% each—and approximately 30% of the population being White (*Los Angeles Times*, 2013b). This neighborhood is generally wealthier than that of Presidential High, with a median household income of $58,483 (2008 dollars) (*Los Angeles Times*, 2013b). The unemployment rate is near the state average (12.5%) at 13.7% (UCLA IDEA, 2011b). Compared to the rest of the city, there is an average number of foreign-born residents (33.9%) primarily from Mexico and Korea with a higher than average number of residents holding four-year degrees (45.2% of residents) in the area (*Los Angeles Times*, 2013b).

City High's computer science students had two classrooms: Mr. Santos's math classroom (that had a cart filled with Mac laptops that students could share) and a computer lab (that was also used by other classes). The computer lab was a poorly air conditioned hotbox filled with ancient PC desktops covered in graffiti etched onto their glass screens and plastic casings. Since this computer lab was shared with other classes, students could not depend on their classwork being saved to the computers. As a result, many student projects were lost or erased and had to be recreated throughout the school year. Still, this did not hinder either Mr. Santos's or students' uses of the computers, and students never complained about the computers, even when their screens were flickering or discolored.

Similar to Presidential High, this school is one of the older secondary schools in Metro City. However, the environment felt completely different from Presidential High. While a police car was often parked in the front of this school, an officer did not stand guard at the school's entrance and adults did not march through the hallways yelling at students to return to class. The school felt more relaxed and open—with a familiar face always greeting me at the main

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entrance—and the student bathrooms were never locked. The school was located on a busy street in the neighborhood and across from a small green space, both of which received a lot of foot and automobile traffic from people unrelated to the school. Nicely-maintained, small-family homes surrounded the school that was only blocks away from busy restaurants and Korean shopping malls to the East, movie theaters and film industry buildings to the North, small Jewish and Ethiopian ethnic enclaves to the West, and large chain restaurants, cafes, and shopping establishments to the South.

Midtown High School

Midtown High was the newest of the three dissertation schools and opened only a couple of years before this study began as a result of a collaborative effort between Metro Unified and a local state university. This public high school was located on a site in the center of Metro City's Koreatown near several bus lines and a recently constructed metro line. New buildings were being built nearby on a regular basis. The school was on a location where several other small schools had also opened—sharing a large campus—many of which offered dual-language programs in Spanish and Korean. Midtown High was a smaller school, enrolling 978 students during the 2011-12 school year of which 77.3% were Hispanic/Latino, 14.9% were Asian American, 3.1% were Filipino, 2% were African American, and 1.2% were White (Ed-Data, 2013c). Over half of the students (54.6%) were English Language Learners with home languages including Spanish, Korean, Filipino or Tagalog, Bengali, and Arabic (Ed-Data, 2013c). The majority of students qualified for free/reduced price meals (Ed-Data, 2013c). Midtown High's teachers were mostly Hispanic/Latino (41.3%) and Asian American (30.4%), but also included 2.2% African American and 21.7% White educators (Ed-Data, 2013c). Similar to the other schools, Midtown High was in its second year of Program Improvement Status, with an API base

measured at 659 out of 1,000 (Ed-Data, 2013c). As a newer school, there is no data available about the trajectory of 9th graders who successfully graduated and entered state universities since many of Midtown's first class of 9th graders are still enrolled in high school.

As previously noted, Midtown High sits within a busy and lively area of the city known for its diversity. The community is 32.2% Asian American, 53.5% Hispanic/Latino, 4.8% African American, and 7.4% White (*Los Angeles Times*, 2013c). This median household income is closer to that of Presidential High and is low compared to the Metro City average, at $30,558 (2008 dollars) (*Los Angeles Times*, 2013c). 21.4% of residents 25 and older have a four-year degree and 68% of residents are foreign born, primarily from Mexico and Korea (*Los Angeles Times*, 2013c).

Midtown's Campus was very vibrant and clean, with its new buildings and modern architecture. Within Midtown High's area of campus, students mingled with teachers throughout the hallways and it appeared as if most people knew each other, if not by name then definitely by face. Teachers and staff would loudly greet students in the hallways, and their exchanges were usually friendly and warm. Students from the high school could regularly be seen interacting with the elementary and middle school students on their campus, with teenagers waving at little children within eyesight. There was a sense of intimacy most likely supported by the school's smaller size in comparison to the other dissertation schools.

Midtown students met regularly in Ms. Mendoza's classroom that had brand new whiteboards, projector, and sound system. However, since Ms. Mendoza usually taught history she did not have a fully-outfitted computer lab. Still, students had regular access to a cart filled with new Mac laptops, enough for one computer per student. While this laptop cart was shared with other classrooms and had to be reserved specifically for this Discovering Computer Science

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course, Midtown seemed to have a dependable laptop-sharing system and students always had computers available when they needed them for classwork or assignments.

<u>Portraits of Mr. Torres, Mr. Santos, and Ms. Mendoza – Three Strong Teachers</u>

Mr. Torres was a male, Puerto Rican American from New York City who was in his thirties. Mr. Torres had been teaching in Metro City public secondary schools for five years at the time of this dissertation research. Previous to becoming a teacher, Mr. Torres worked in the IT industry until he realized, "I want something that is more rewarding, more meaningful than just fixing computers or troubleshooting peoples' technology issues" (P.T.Int1.12.14.11). His boss at the time allowed him to change his work schedule so that he could take the coursework necessary to become a secondary school teacher, and after several years Mr. Torres received his teaching credentials in Industrial Technology and Information Technology. His charisma and experience made him a leader at Presidential High, and especially within his Small Learning Community (SLC) focused on business and communications. By his second year at Presidential High, he was in charge of creating a technology pathway for students in his small learning community that included internet publishing, CISCO training, computer service repair, and Discovering Computer Science. Mr. Torres was also active in school athletics, coaching basketball and football teams at his school, which meant that he was regularly on campus or going to games with students well after 6pm on most days. Mr. Torres also regularly organized field trips to college fairs and university site visits in an effort to encourage students to pursue post-secondary education. The positive relationship Mr. Torres had with students at Presidential High was obvious in the ways students regularly came by his classroom to wave hello in between classes or during breaks. Mr. Torres usually kept his classroom open for students to use during lunch.

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During my dissertation pilot study, I had the privilege of observing Mr. Torres teach Discovering Computer Science classes on a regular basis. It was at that time that I realized his strengths not only in the social community of Presidential High, but also at supporting student learning of computer science problem solving skills. He kept students excited about learning computer science and his class resulted in various strong projects in website design, animation, and game design.

Despite Mr. Torres's dedication to the school community and high engagement with students' academic and extracurricular lives, he received a "pink slip" during the beginning of the MyData curriculum implementation in spring 2012, indicating that he would be losing his teaching position in the fall due to budget cuts. This news came as a complete shock to both Mr. Torres and his fellow teachers in his SLC, several of whom tried to help Mr. Torres find loopholes in the system that would ensure he could find a teaching position at another school in the fall. Students were dismayed that they would be losing one of their favorite teachers. Mr. Torres appealed to the district and scheduled a hearing regarding his case with Metro Unified. I personally wrote a letter attesting to his dedication to teaching and professional development through Discovering Computer Science. Despite the stress of this situation that occurred during the MyData implementation, Mr. Torres did his best to remain focused on teaching his students and told me that he did not want the students to suffer for the failures of the school district. While Mr. Torres was able to get his pink slip repealed and remain a teacher in Metro Unified, Mr. Torres had to leave the Presidential High community and find a new school while he was busy teaching and wrapping up the 2011-12 school year.

Mr. Santos was a Mexican American male in his forties who had grown up as a migrant farmworker in Central California, serving as a translator between Mexican farmworkers and non-

Mexican farm managers/owners as a child. While Mr. Santos had a passion for aerospace engineering, he discovered his love of teaching while working as a TA in an elementary school. Mr. Santos began his teaching career in 1996 as a mathematics and ESL teacher. During his career, Mr. Santos taught primarily at City High (over a decade collectively) but also spent two years teaching up in a farming community North of Metro City in the mid-2000s. Similar to Mr. Torres, Mr. Santos was active in his school community and built strong relationships with his students. During this study, Mr. Santos was serving as the senior class teacher representative which involved large time commitments while assisting these 12th graders in preparing their homecoming, prom, and grad night events through constant fundraisers and planning meetings. Mr. Santos regularly had seniors meeting in his classroom during lunch and after school.

As a dependable member of the schooling community, parents often turned to Mr. Santos to watch over their children and communicate with them if issues were to arise. His ability to communicate in Spanish and his respectful, caring attitude drew many students and families to him. It was not unusual for Mr. Santos to receive emails or college graduation invitations from previous students who he had taught many years before. This was not surprising considering how Mr. Santos viewed his students: "I'm a parent, and as a parent, when I look at kids, I look at them like, 'What if this child would have been mine?'" (C.T.Int2.6.4.12). Mr. Santos treated his students as he would want his own children to be treated, emphasizing the importance of having them feel safe and enjoying the learning experience (C.T.Int2.6.4.12).

I first met Mr. Santos during various Discovering Computer Science teacher professional development events that I helped to organize and lead. It was in these contexts that I was able to observe Mr. Santos as he demonstrated his teaching skills in front of his colleagues and shared his pedagogical insights during whole-group discussions. One of the Discovering Computer

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Science coaches who visited him weekly during his first year teaching computer science (in the 2010-11 school year) shared her observations with me and suggested that I work with him during my dissertation research due to his strengths in the classroom.

Ms. Mendoza was a Mexican American woman in her late twenties who identified as a "queer Latina" and "social justice educator" (M.T.Int1.12.9.11). Ms. Mendoza was raised in Metro City and came from a family of educators (her mother was a principal, her sister a science teacher, and her aunt an elementary school teacher). While Ms. Mendoza was certified as a history teacher and taught primarily middle school students, due to her enthusiasm and role as a technology coordinator at her school, she became a Discovering Computer Science teacher for high school students. She was dedicated to professional development, taking online Java courses and various other workshops throughout the school year that would enhance her teaching practice. She also volunteered to teach a Scratch programming course for middle school students at Midtown during her first year teaching Discovering Computer Science. Beyond her responsibilities as a technology coordinator, history, and computer science teacher, Ms. Mendoza also volunteered to attend a Scratch programming workshop in Boston and present at conferences as a teacher leader of Discovering Computer Science. Ms. Mendoza had a strong and positive relationship with the other teachers at the school. These Midtown teachers could regularly be found eating lunch together and discussing collaborative efforts for both teaching and school social events. Ms. Mendoza also had warm interactions with her students and could often be found joking and laughing with children and teenagers of all grade levels at her school.

I invited Ms. Mendoza to be a part of my dissertation study soon after I met her during a Discovering Computer Science professional development in summer 2011, and I began observing her class shortly thereafter in fall 2011. At the start of the school year, I had the

opportunity to see the ways she developed a learning community with her computer science students and successfully engage them in computational thinking practices. Ms. Mendoza demonstrated strong teaching skills. After visiting her regularly during the first several weeks of school, she agreed to participate in my dissertation study.

<u>Why Were These Schools Chosen?</u>

There are several reasons why I purposefully chose these three schools for my dissertation research.

First of all, I wanted to challenge the simplified ways our mainstream media sources define life in "these" schools and their surrounding neighborhoods. Most people are not surprised to see that schools enrolling low-income students of color have lower standardized test scores compared to the state average. Indeed, many people *expect* that schools comprising low-income students of color should be floundering on their examinations because of the students' socioeconomic class and racial/ethnic makeup. Consider, for example, how researchers like Abigail and Stephan Thernstrom (2003) posit that low standardized test scores in schools enrolling children of color are the result of Latino/a and African American students' poor "attitudes" toward schooling and not a problem with the testing system itself. The racist assumptions underlying this perspective include that Latino/a and African American students are born *without* a "culture conducive to high academic achievement" (p. 99), do not appreciate schooling, and simply do not work hard enough (Thernstrom & Thernstrom, 2003). Educational researchers like the Thernstroms argue that Latino/a and African American students should learn from their Asian American peers who purportedly succeed in schools because of their "hard work" and cultural love of education that matches their White counterparts (Thernstrom & Thernstrom, 2003, p. 4). This "deficit" thinking—one that marks certain cultures better than

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others and "blames" Latino/a and African American students for arriving to school with a "deficit" of superior cultural knowledge—takes a hierarchical and static view of "culture" while promulgating the "Model Minority Myth" that all Asians (a racial group including over thirty different ethnic subsets with varying immigration histories, class backgrounds, and educational trajectories) achieve equally high educational and economic success (Dabney, 1980; Ryan, 1971). Thinking even beyond the plethora of evidence showing that Latino/a and African American students *do* care about school (Suárez-Orozco & Suárez-Orozco, 1995, 2001; Thompson, 2003), the Thernstroms' logic takes on a reductionist assumption that all members of a racial group share the same view of their own culture, with Latino/as and African Americans engaging in "wrong" cultural practices (e.g., regarding language or music) and Whites engaging in what is superior and "normal," practices to which Asians smartly aspire (González, 2005). This reasoning fails to recognize how factors outside of school, such as lack of health care, housing, and food, affect students inside of school. Simply teaching students of color how to live according to White, middle-class values—that the Thernstroms hail as central to educational reform—will not address a homeless student's housing or nutritional needs.

Rather than supporting the belief that Latino/a, African American, and Asian American youth represent singular cultures, belief systems, and practices built solely on the color of their skin or the ways that they speak English, this dissertation attempts to create a space where the richness and vitality of diverse teachers and students may be expressed and shared. Furthermore, I chose *not* to compare these schools to a wealthier, White school because I did not want to focus on the binary thinking of White vs. person of color, rich vs. poor, etc., that such studies often engage. While I certainly value educational studies that highlight how economic structures, power, politics, and various institutions have shaped the schooling experiences of low-income

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students of color to be different from those of wealthy, White students, such is not the purpose of my study. Instead, I wanted to provide descriptions of non-dominant learning communities and their most effective teaching/learning practices in an effort to emphasize the strength and resilience of these communities instead of their weaknesses or what they lack.

Secondly, due to previous experiences within these schools and engagement with their teachers and students through my dissertation pilot study and work in Discovering Computer Science, I understood that the three teachers participating in my dissertation study—Mr. Torres, Mr. Santos, and Ms. Mendoza—were particularly strong educators and highly-regarded in their communities. While standardized test scores were low at these schools, this does not mean that all teachers were poor at their craft. Thus, I made efforts to focus on teachers who might give insight into *effective* teacher practice in these diverse school spaces, adding to conversations about "what works" in schools instead of "what doesn't work."

Thirdly, returning to my literature review in Chapter Two regarding the lack of diversity (race/ethnicity and gender) in computer science, I wanted to share the stories of diverse students and educators who are successfully learning and teaching computer science in a way that counters the tendency to assume that people of color and women don't pursue computer science because of a lack of interest or ability. As I found to be true in all three schools, both females and students of color *are* interested *and* capable of excelling in computer science. Yet, if we want to broaden participation in computing for diverse students, we need to understand which teacher practices and curricular tools successfully engage a wider audience of youth within school spaces. Thus, I chose to describe classrooms in public schools that could provide perspective on the ways diverse students could be engaged in computational thinking and 21st century learning with computer science, *despite* the constraints often experienced in urban public education (e.g.,

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the budget cuts that resulted in Mr. Torres losing his job at Presidential High). The three teachers and their classrooms described in this dissertation offer an important perspective regarding what secondary computer science education could be in public schooling spaces.

Research Context: The Discovering Computer Science Course and MyData Curriculum

<u>Discovering Computer Science</u>

This dissertation took place within three classrooms employing a new course called "Discovering Computer Science" (DCS). DCS is a year-long course which was first piloted in six Metro City Unified High Schools during the 2008-09 school year, and that is currently being taught for G-credit[16] in approximately twenty, MCUSD public high schools. Funded by the National Science Foundation, DCS was created in response to previous research findings that revealed how the majority of our nation's high schools—especially high schools enrolling high numbers of African American and Latino/a students—do not offer quality computer courses such that most students are only exposed to basic word processing skills instead of the higher order, computational thinking of computer science (Goode, 2007; Margolis et al., 2008). The DCS curriculum was developed with the purpose of broadening participation in computing to a more diverse population of students through inquiry-based learning intended to be socially relevant and meaningful. DCS's six units introduce students to the foundational, creative, collaborative, interdisciplinary, and problem-solving nature of computer science covering the following topics: human computer interaction, problem solving, web design, programming, animation, robotics, and data analysis.

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[16] G-credit is one of seven credits (called "A-G credit" collectively) that high school students must take to be considered eligible to apply for state universities/colleges. Many students in Metro City do not complete the A-G requirements, despite being allowed to graduate from high school and to receive a high school diploma.

I have personally worked with all the MCUSD teachers who taught DCS since its pilot year in 2008-09 into the present. I am in regular contact with DCS teachers and know each educator on a first-name basis through my participation in professional development activities, online discussions, research observations, and social gatherings.

DCS offers a unique professional development program designed to build off of teachers' wealth of knowledge while supporting their growth as leaders in the national computer science education community. Teachers meet for two weeks every summer and approximately once a month throughout the school year to learn about various DCS lesson objectives, practice teaching activities, discuss issues, and share resources with one another. The DCS program also employs three coaches who visit teachers in their classrooms to offer pedagogical and computer science content knowledge support.

The MyData Curriculum

The innovative, mobile phone-based curriculum studied in this dissertation research was taught as part of the DCS course's introduction to data analysis during the 2011-12 school year. The first part of the curriculum—which involved teaching students about how data are collected, analyzed, and represented in the context of daily human-computer interactions (on the internet, through social networking, etc.)—was taught during a period of approximately four to six weeks in fall 2011. The second and main part of the curriculum—which involved conducting research using mobile phones and analyzing data using computer software—was taught during a period of approximately six weeks during spring 2012. This MyData curriculum was based in "participatory sensing," which is a form of research designed by the UCLA Center for Embedded Networked Sensing (CENS). Participatory sensing offers people the opportunity to conduct "citizen science," or their own research projects using smart phones in order to

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document environmental and social processes where they live, work, play, and experience daily life (Burke, Estrin, Hansen, Parker, Ramanathan, Reddy, & Srivastava, 2006). As described by Burke, et al. (2006):

> *Participatory sensing* will task deployed mobile devices to form interactive, participatory sensor networks that enable public and professional users to gather, analyze and share local knowledge. Microphones and imagers on-board the mobile handsets can record environmental data now, while in the future other sensors will be integrated or connect wirelessly. Cell tower localization, GPS and other technologies can provide location and time-synchronization data. Wireless radios and onboard processing enable human interaction with both local data processing and remote servers…encouraging participation at personal, social and urban scales. (p. 1)

When brought into a high school classroom, participatory sensing offers a valuable opportunity for students to not only design and conduct their own science-based research projects using mobile phones, but also to learn how to analyze and represent data that they can share with a wider audience toward potential, social change. Students engaging participatory sensing with mobile phones have the chance to be active democratic participants by engaging research in their communities and sharing their work with others regarding a topic that they find particularly important.

Previous UCLA CENS examples of participatory sensing projects using mobile phones include "GarbageWatch," "Biketastic," and "What's Invasive." In GarbageWatch, college students collected information about trash receptacles on campus in a form of "waste audit" that involved sending formatted SMS messages describing how people were using (or improperly using) waste and recycling bins in different areas. Through this project, students were able to note if people were failing to recycle due to a lack of recycling receptacles in certain areas and, therefore, were able to advocate for putting more recycling bins around campus. In Biketastic, participants logged details about their personal bicycle rides around the city with images, text, and GPS traces. Through this project, students were able to provide information on air quality,

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traffic conditions, and safety issues along commonly traveled bicycle routes that could be shared with other cyclists in the community. This project offered the potential of improving safety and bicycle-riding quality for the city's cyclists and bicycle commuters. Finally, What's Invasive allowed students with GPS-enabled mobile phones to collect geo-tagged images of specific habitat-destroying, invasive plant species. This information proved useful for preserving local natural habitats.

During the 2011-12 school year when the MyData curriculum introduced participatory sensing to DCS classrooms, high school students studied advertising in their communities and personal snacking habits. For the advertising project (implemented only at City High), students completed surveys on mobile phone apps that asked questions about advertisements (e.g., billboards, bus stop posters, etc.) seen in students' neighborhoods. Questions on this advertising survey app prompted students to take a photo of the advertisement and then answer the following: 1) Describe the product (open-ended); 2) Select which advertisement type it is (billboard, digital display, poster, or bus); 3) select the product type (food and drinks, entertainment, electronics and apps, clothing, shoes, accessories, home, or beauty); 4) Describe the target audience (open-ended); 5) Rate how much you want the advertised item (1 least desirable, 5 most desirable); and 6) Describe how the ad makes you feel (open-ended). See Appendix A for more details.

For the snacking project, which was implemented at all three schools, students answered survey mobile phone app questions including: 1) When did you eat your last snack? (mid-morning, mid-afternoon, evening, late night, non); 2) What did you eat? (open-ended); 3) How healthy was the snack? (rating from 1 very unhealthy to 5 very healthy); 4) Where did you eat? (home, school, work, restaurant, friends' houses, vehicle); 5) Who were you with? (alone,

family, friends, classmates, co-workers, other); 6) Why did you eat? (open-ended); 7) Approximate snack cost (less than $1, $1-3, $3-5, $5-7, $7-10, more than $10); 8) How many snacks have you missed reporting since your last entry (0+); 9) Take a photo of your snack. See Appendix B for more details.

Each time a student completed a survey on their mobile phone, the survey answers were uploaded to a website (called the "Web Front-End") where students could view their own and classmates' data as they were uploaded in real-time. Student identities remained anonymous on this website through randomized, number-based login ID's, and the website was only accessible by login and password in order to protect students and their data.

During the data collection period, students practiced using data analysis software created specifically for this curriculum. This software, called "JGR" or "Deducer," was a Graphical User Interface (GUI) built on top of the "R" statistical analysis program. Students could use either JGR/Deducer features or enter data analysis commands directly into the R program using this software. Using other data sets from the Center for Disease Control and Prevention or Twitter, students learned how to build various types of graphs and draw conclusions from these data representations. At the end of their data collection period, students then applied their new skills with JGR/Deducer to analyze their own data sets. The final project assignment included students' conclusions regarding their research data about advertising, snacking, or both.

While MyData offered students a chance to learn valuable skills in democratic participation and scientific research, this curriculum also taught students about the diverse roles that data play in our daily lives: how data originate, move, and translate. MyData incorporated math and statistics to help students make sense of information collected with the mobile phones.

The MyData activities in DCS directly addressed the challenges described in Chapter Two: instead of simply assuming that our Generation Z high school students know how to use technology in meaningful ways because of their regular use of such technology for socializing or playing games outside of school, MyData was designed to teach teenagers how to creatively use such technology *inside of school* in ways that supported critical thinking, computational thinking, and 21st century problem solving skills. Instead of teaching students to be mere consumers of other peoples' technological advancements, MyData was developed to engage students to be producers of new knowledge by showing them how to conduct community-based research using mobile phones. Furthermore, MyData brought to the forefront many of the ideas that critical pedagogy (described in Chapter Three) makes central in the need for educational reform: schools are reflections of, and intertwined with, the power struggles and politics of the world surrounding them, however students and teachers alike can help transform the oppressive nature of power-based/political imbalances by working together toward social change through their own research and community work. By giving students the opportunity to share their personal perspectives and stories in mobile phone-based research projects, and by offering the chance for teachers to support student learning through that process, the MyData curriculum represented a form of critical pedagogy for public computer science classrooms.

Data Collection Process

Data Collection Overview

This research was approved by the Office of the Human Research Protection Program at the University of California, Los Angeles under Institutional Review Board forms #10-001701 and #10-000146. Data sources collected included: 1) observation field notes of class meetings; 2) video footage of observed class meetings; 3) video footage of students presenting their final

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MyData projects; 4) research memos; 5) personal journals; 6) informal teacher interviews at the end of the first semester (December 2011) and the end of the MyData spring implementation (May/June 2012); 7) informal student interviews at the end of the school year following MyData spring implementation (May/June 2012); 8) Discovering Computer Science student surveys regarding self-perception related to computer science and computer science topics (completed at the start of the school year in fall 2011 and end of the school year in May/June 2012); 9) student pre- and post-surveys regarding the MyData curriculum and data analysis topics as designed by the National Center for Research on Evaluation, Standards, & Student Testing (CRESST); 10) and student work (e.g., homework assignments, journal entries, advertising and snack data collected with mobile phones, final projects). An overview of the timeframe during which the above data sources were collected is shown below:

Date	Activities	Schools
June 27 – July 30, 2011	• Discovering Computer Science Summer Professional Development	Presidential, City, & Midtown
July 5-14, 2011	• MyData Summer Professional Development	Presidential & City
August 2011	• Daily observations (starting August 16) • Student DCS Pre-Survey (August 24)	Presidential
September 2011	• Daily observations • Student DCS Pre-Survey (City High; September 15)	Presidential, City, & Midtown
October 2011	• Daily observations	Presidential, City, & Midtown
November 2011	• Daily observations	Presidential, City, & Midtown
December 2011	• Daily observations • Informal Teacher Interviews	Presidential, City, & Midtown
January 2012	• Observations once a week	Presidential, City, & Midtown
February 2012	• Observations once a week	Presidential,

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	• Two MyData Professional Development Days (February 11th and 25th)	City, & Midtown
March 2012	• Daily observations (City High starts MyData on March 26; Presidential High starts MyData on March 28) • Mobile phones distributed • Observations once a week (Midtown)	Presidential, City, & Midtown
April 2012	• Metro Unified Spring Break (April 2-6) • Daily observations • Midtown starts MyData on April 17 • Phones distributed to Midtown High • MyData Student Pre-Surveys Completed • Presidential and City High State Standardized Testing	Presidential, City, & Midtown
May 2012	• Daily observations • Presidential High Completes MyData Unit and MyData Student Post-surveys on May 11 • City High Completes MyData Unit on May 14, 2012 and Student Post-surveys on May 18 • Presidential High DCS Student End-of-year Survey Completed; Last day of school on May 25 • Students interviewed • Mr. Torres Post-MyData interview	
June 2012	• Daily observations at Midtown • Midtown Completes MyData Unit on June 8; MyData Student Post-surveys completed • DCS Student End-of-year Surveys completed • Observations once a week at City and Midtown until last day of school on June 19 • Students interviewed • Mr. Santos and Ms. Mendoza Post-MyData interviews	Presidential, City, & Midtown

Figure 4.1*: Timeline of MyData-related activities and data collection processes.*

Classroom Observations – Field Notes and Video Footage

I was present in all three classrooms from the very beginning of the school year in fall 2011. This allowed me to develop comfortable relationships with teachers and students (who came to expect me in the classroom every day) while observing how classroom community norms were established during the first several months of school. All data-related activities found in DCS Unit 1 ("Human-Computer Interaction") that formed the foundational concepts for the

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MyData curriculum were carefully observed. All problem-solving activities found in DCS Unit 2 ("Problem Solving") that illuminated the ways teachers taught problem solving processes and critical thinking skills were also carefully observed. Thus, I was present in all three classrooms at Presidential, City, and Midtown High Schools on a daily basis from late August 2011 until all schools completed Unit 2 in early December 2011. Once teachers had completed teaching Unit 2 regarding problem solving, I continued to visit all three schools once a week (through January, February, and March 2012). When teachers began teaching the MyData Unit and students received their mobile phones (end of March 2012 at Presidential and City High, mid-April 2012 at Midtown High), I began visiting the classrooms on a daily basis again, observing all lessons and activities related to this data analysis unit. Video footage was recorded during every class meeting that I observed that covered the first two units and the MyData curriculum. Observation field notes were written on a daily basis within four hours of every school visit. I made sure to separate my personal reactions (through "observer comments") from my actual observations of actions/interactions in the classrooms. As described earlier in this chapter, I chose to focus on the unit of analysis of "shared practice." Field note observations described in detail the social interactions occurring between classroom community members, conversations, relationships, teacher actions, student actions, forms of assistance that teachers and students provided for one another, and uses of technological tools.

Interview Data Sources

Informal interviews were conducted with teachers at the end of the first semester (in December 2011) and immediately following completion of the MyData unit (May and June 2013). Interview questions for December 2011 were developed in relation to teachers' personal histories and experiences with Discovering Computer Science. Questions covered topics such as

teachers' personal backgrounds in education and computer science, teaching style, approaches to inquiry-based teaching, ideas about classroom culture, teaching philosophy, teaching goals, student learning examples, equity issues, and DCS program experiences in professional development and with coaches. The complete list of interview questions can be found in Appendix C. Teacher interviews conducted in May and June 2013 after the MyData curriculum was implemented included questions that emerged from classroom observations regarding teaching practice and student learning. These questions were developed with the intention of confirming and/or challenging initial hunches and findings from my preliminary coding of fall 2011 field note observations as well as from research memos written during the course of the MyData curriculum implementation. Questions covered topics such as teaching philosophy and pedagogical strategies for computer science education (related to initial themes and codes emerging from the fall 2011 field notes and recent MyData research memos), teachers' experiences teaching MyData lessons, teachers' learning goals for students through the MyData activities, and MyData technological tools and curricular resources. The complete list of spring 2012 teacher interview questions can be found in Appendix D.

Informal interviews were conducted with students at the end of the school year as they completed the MyData unit and the Discovering Computer Science course (in May and June 2012). Similar to the spring 2012 teacher interviews, questions for students emerged out of initial coding of field notes and research memos in relation to effective teacher practices and major ideas/skills learned through the MyData research project. These interview questions can be found in Appendix E. Student interviews were conducted with a total of forty-seven students: sixteen students at Presidential High, eighteen students at City High, and thirteen students at Midtown High. I made sure to interview a range of students from the most engaged to the least engaged as

reflected through both observations and students' course grades in Discovering Computer Science. The number of male and female students interviewed in each school also intentionally reflected the ratio of males to females in each classroom. The breakdown of students interviewed at each school based on gender and engagement in Discovering Computer Science is shown in the table below:

School:	Presidential	City	Midtown
Female:	7	7	7
Male:	9	11	6
Highly Engaged:	5	7	6
Engaged:	8	8	6
Disengaged:	3	3	1
Total:	16	18	13

Figure 4.2: *Student Interview Chart; Data Collection*

The low number of disengaged students interviewed in each class reflected my difficulty in finding disengaged students to interview in these classrooms. In all three classrooms, most students were generally excelling with the Discovering Computer Science curriculum and highly engaged in the MyData curricular project. Still, at least two students forgot to meet for an interview at the appointed time and place. After forgetting twice in a row, I would not push these students to reschedule in case their "forgetfulness" actually reflected discomfort with being interviewed. The majority of students who were interviewed, however, showed great interest and pride in sharing their perspectives about DCS and the MyData project.

Survey Data Sources

Survey data were collected from two different sources: the Discovering Computer Science project and the MyData Evaluation Team headed by CRESST.

The student survey developed for evaluating the Discovering Computer Science project addressed questions of student self-efficacy and interest in computer science. Questions such as "What do you want to learn about computing/computers in this class?" and that asked students to

rate whether they strongly agree, agree, disagree, strongly disagree, or are not sure about statements such as "The challenge of computer science does NOT appeal to me" were included on the survey. The DCS pre-survey can be found in Appendix F. The DCS post-survey implemented at the end of the school year included some additional questions related to what students learned in the course and best liked in the course. The DCS post-survey can be found in Appendix G. These surveys were completed by students at the start and end of the 2011-12 school year using *surveymonkey.com* in an effort to document any changes in student perspectives before and after taking DCS.

The CRESST pre- and post-MyData survey for students included questions about students' access to technology (internet, computers, etc.), ease of using MyData technology (mobile phones, web front-end, etc.), likes and dislikes about the MyData project, perceived importance and meaning of the MyData project, and attitudes toward computer science. There were also two performance-based assessments to measure students' computational thinking skills both before and after the MyData Unit. One measure included a "*Facebook* task" in which students were given a scenario entitled "Banning *Facebook* in Schools." In this hypothetical proposal from a fictitious student group, a claim was made that time spent on *Facebook* negatively affected academic achievement. Students were asked to critique the data sources and research methods used in this scenario. The second assessment involved a scenario in which students were asked to plan a new community park. Students were given three pieces of data to make various decisions about the park based on a community poll, details about parks nearby, and a city map. Students had to use various data sources to come up with park design plan (see Ong, Griffin, Binning, Delacruz, Byrne, Chow, & Redman, 2012).

All student journals were collected and analyzed in the three dissertation classrooms. Yet, the primary source of student work analyzed in this dissertation came from students' MyData final projects. Unfortunately, only two of the three classes completed final projects. Mr. Torres's students at Presidential High did not complete final projects due to various time constraints. Mr. Torres believed that creating final projects would take up too much time and that he wanted to make sure students would be able to learn about robotics before the year ended. Thus, Mr. Torres analyzed data with his students collectively instead, facilitating students' processes of building various plots with their data and drawing conclusions from these plots as a group.

At Midtown and City High, all final projects were collected on the last day of the MyData Unit. If the project was digital (e.g., Powerpoint, website, Scratch animation project, film), then it was saved to a jump drive. If the project was a 3-dimensional poster or physical representation, then it was photographed using a digital camera. These photographs (in .jpg format) were stored on the same jump drive. Video footage of students presenting their final projects to peers and teachers was also recorded on the final day of the MyData Unit at both Presidential and City High Schools.

Research Memos and Personal Journals

Memos served as a meaning-making space for the observations made during my interpretive participant observation visits. These research memos were written at least once a month during the fall and MyData Unit observation periods, and included reflections upon the events/interactions observed in relation to my initial research questions. Through this process, my research questions began to evolve and new lines of inquiry emerged. These memos provided

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me with the time and space to think about how my daily observations fit into the larger scheme of the research project.

In order to also address how my personal role in the classroom as an interpretive participant observer may have affected events/interactions observed or interpretations of such observations, I also wrote in a personal journal at least once a week or more often when inspired to do so. This journal was an informal space that helped push my emotional and psychological attachments that I either brought into the research space or developed during the research project. In this way, I addressed how my own positionality affected both the data collection and analysis processes of this dissertation research.

Data Analysis Process

Coding Data Sources – Grounded Theory and the Constant Comparative Method

Using a grounded theory approach (Glaser & Strauss, 1967), my research analysis involved systematically and repeatedly reviewing the data corpus (field notes, interviews, surveys, memos) while searching for patterns (codes, themes, and categories) that could help guide my assertions about teaching practice and student learning. These assertions were tested with both confirming and disconfirming evidence using the Constant Comparative Method (Erickson, 1986).

I began my first phase of data analysis in December 2011 after completing the initial first months of classroom observation. During this initial review of field notes, teacher interviews, research memos, and student journals, I began to sketch out a general overview, in chronological order, of where the classroom community began, how it moved through the early data and problem solving activities of DCS Units 1-2, and where the community was as a whole by the end of the first semester. Paying close attention to the ways classroom norms were developed

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and how social interactions related to teacher practice or student engagement with computer science activities, I used a "top-down" approach to data construction. I considered the larger, more sweeping patterns of things that seemed to emerge from the entire corpus of research materials in relation to teacher and student actions. Through this process, a series of codes related to teacher practices, student practices, school-related issues, technology-related issues, and researcher practices developed. For example, within the larger parent code under teacher practice grew the code "connections to real life" which included sub-codes such as "real world issues," "tips for life and job opportunities," "college," and "sharing personal stories." Another "teacher practice" code that became salient was "asking questions" that included sub-codes such as "check understanding, "recall/yes/no," "leading question/call-response," and "deeper thinking question." As these codes arose out of this first read-through of my data sources, I considered how they related to questions such as: What kinds of assistance did teachers offer students? How did teachers lead discussions about new computational thinking ideas? How did students respond to teachers' questions? What did student engagement look like?

The patterns and lines of contrast developed through my consideration of these initial questions provided my framework for conceptual categories and a thesaurus of preliminary codes. Then, these preliminary codes were further parsed down as I began to consider "differences in kind," such as kinds of teacher assistance, types of student peer assistance, and ways that students participated in the classroom. Through this "top-down" analysis process, I began seeing patterns within the data that illustrated ways that social practices developed in these classroom communities and how students' ways of interacting or thinking shifted over time.

However, I also employed a "bottom-up" approach to analyzing these data sources by looking for specific instances that did not initially appear to be related to larger patterns in my

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initial read-through of materials, pointing to new conceptual categories and codes. These instances helped enrich and complexify my analysis process so that I did not miss the smaller details of social interactions between teachers and students as well as students and students.

During this first read-through and coding process, I was careful to avoid binary-type codes that might limit my understanding of the nuances of teacher or student practice. For example, instead of coding for "effective" vs. "ineffective" teacher questions, I chose to code for the various types of questions teachers asked of their students. Also, recognizing that the three dissertation classrooms/schools were very different from one another, I began the coding process by first developing themes for individual schools, then overlaying these themes across schools in search of similarities in teacher and student practices. This helped me understand what pedagogical practices were unique to specific teachers as well as shared by these very different educational personalities and classroom communities. Finally, I made efforts not to judge what I believed to be "good" or "bad" teaching or learning and regularly journaled about this topic through the coding process. Instead of placing my educational perspective on the codes that emerged, I searched for patterns in teacher practice that overlapped with student engagement practices in the computer science classrooms (e.g., student participation in computer science activities, eagerness to share ideas in whole-group discussions). Through this first coding process, I began to develop preliminary assertions about effective pedagogy that proved common across all three schools, as well as student engagement with learning about data analysis.

As a result of this first pass at coding the fall observation field notes, during the spring MyData Unit I began to focus more on student-to-student practices whose descriptions I felt were lacking in my first set of field notes. At the same time, my research questions became more

nuanced which helped clarify my observation focus on the unit of analysis of "shared practice" in a new way.

Near the end of the MyData Unit, I began to develop my interview questions for teachers and students as a way to confirm and/or challenge the initial assertions about teaching and learning that had emerged through my first set of coding and new field note observations. When all data sources were collected by June 2012 and I had completed transcribing all teacher and student interviews, I began my second round of coding. This involved reading through all field notes, interviews, and surveys, while using the Constant Comparative method (Erickson, 1998) to check for the validity of all preliminary assertions while revising codes and themes, seeking out discrepant evidence that challenged my preliminary assertions or complicated any narrow understandings of the classroom.

Following this coding process, I created counts for codes and frequency tables in order to numerically portray potential commonalities across schools. For example, I developed a frequency table of student engagement practices related to teacher humor that emerged through the coding process. This further strengthened and challenged my assertions about pedagogy and student learning in these Discovering Computer Science classrooms.

Student Final Project Analysis Process

Final projects were analyzed using a four-step approach: 1) all final projects were reviewed for content and format using a rubric (detailed below); 2) using this rubric, three projects from each school (one typical "weak" project that met few of the rubric requirements, one typical "average" project representing the content and style of most final projects in the class, and one typical "excellent" project exceeding rubric expectations) were selected for closer analysis; 3) these three projects from each school were then carefully analyzed using multimodal

methods (described in detail below); and 4) when available, video footage of students presenting these three projects on the final day of the unit was also analyzed using the same multimodal methods used for final project artifact analysis.

The rubric used for initial student project review focused on both content and format. This rubric covered:

1) Research questions raised.
2) Conclusions/hypotheses drawn from the data.
3) Plots and text used to illustrate or explain the student's conclusions/hypotheses.
4) Other images used to illustrate/explain the student's argument or ideas.
5) Description of study limitations.
6) New question(s) raised through the project.
7) Final project design (looking at both the project's physical format—website, Scratch project, poster—and attention to aesthetic detail).

This rubric can be found in the Appendix H.

While conducting the rubric-based, initial review of all student projects, common themes in students' conclusions and ways of presenting these conclusions were noted. More specifically, codes were assigned for:

- Sophistication of graphs/plots (e.g., 2 or more variables, subsetting data).
- Accuracy of graph/plot interpretation.
- Complexity of thinking (Did the student raise new questions? Did the student consider how data collection practices affected data analysis?)

Furthermore, unique ideas shared by individual students or projects were also recorded. For example, if a student questioned her/his research findings in a way that was different from their peers or if a student presented her/his data in a way that was uncommon in the classroom, these details were noted separately for consideration.

Multimodal Methods for Examining Student Projects

Multimodal methods were used to carefully analyze both student projects and video footage of students presenting their work. This is because 21st century technological

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developments infiltrating all areas of everyday life have impacted human communication so dramatically that "how knowledge is represented, as well as the mode and media chosen, is a crucial aspect of knowledge construction, making the *form of representation* [emphasis added] integral to meaning and learning more generally" (Jewitt 2008, p. 241). Speaking specifically about literacy, Kress (2003) explains that we cannot focus on language and print literacy alone to understand reading and writing because of two major factors: "on the one hand, the broad move from the now centuries long dominance of writing to the new dominance of the image and, on the other hand, the move from the dominance of the medium of the book to the dominance of the medium of the screen" (p. 1). Indeed, writing is no longer the main mode of communication between people as it is both combined with, and even replaced by visual and other multimodal forms of representation through various new media technologies (Adkins, 2005; Bachmair, 2006; Jewitt, 2008). Multimodal research methods attend to meaning making as constructed beyond the written word through "modes" such as image, sound, gesture, gaze, posture, music, and speech (Jewitt, 2008; Kress & van Leeuwen, 2001).

Within the context of technology-based, computer science classrooms where teaching and learning are mediated through the use of computers, mobile phones, and other new media technologies, multimodal methods examining communication beyond the written word becomes even more salient. Thus, in order to make sense of student learning in the MyData Unit, I employed multimodal analysis methods to examine both students' final projects as well as video recordings of students presenting their work.

Building off of multimodal analysis methods as described by Kress and van Leeuwen (2001) as well as Bezemer and Jewitt (2010), I employed the following steps for examining student projects and video footage of students presenting their final projects.

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For examining student work, I created "project logs" describing different physical excerpts of each student project (e.g., web page space, poster panel, animation scene) with thumbnail sketches of those excerpts. Observer comments including my provisional analysis was also written alongside these logs.

Similarly, while viewing videos of student presentations, I began by creating video logs describing students' acts of presenting their projects that included sketches and comments about physical movements, changes in verbal intonation, video stills of the presentation, shifts in gaze, and interactions between students/teacher. Separately, I added observer comments including personal reactions, ideas, and questions.

In the second step of analysis, I would review the data (student projects and video of students presenting) multiple times. With student projects involving animation and videos of students presenting, I would try watching with vision only, sound only, fast forwarding, and in slow motion to provide different ways of understanding and analyzing the data. For student posters, a similar process was used involving covering images and just focusing on text, or covering text and just focusing on images. This helped for recognizing patterns in the data, refining and generating new questions, and developing analytical ideas. These artifacts—student work and video—were then viewed in relation to fieldnotes describing student presentations.

The third step involved transcribing and carefully analyzing excerpts from video and student work. Video excerpt transcription attempted to capture features of speech, such as intonation, pauses, and exclamation, as well as physical movement, shifting of gaze, and physical relationships between the student presenter and others visible in the video footage. Transcription of student work included careful descriptions of image, color, movement, and font as visible through the project.

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CHAPTER FIVE
"Good" Computer Science Pedagogy

"When you learn to swim you can't just throw somebody in the water and expect them to swim, you gotta let them in the shallow water first…Just like that, he…submerges us in the water slightly to get us comfortable talking about the subject…And then slowly, steadily, you just keep going deeper and deeper into the subject, until eventually you just look back and you're like, 'Look at all this work I've done! Look how much I've learned!' And that's really how he gets you subconsciously. You never realize it until it's finished." (James, C.Int3a.5.14.12)

As described by James from City High, skilled teachers know how to immerse students gently in academic learning by making it feel "subconscious." In this way, students do not have time to be intimidated by the subject matter. Instead, learning happens without students "realizing it" until their achievements have accumulated over time. Such a pedagogical approach is particularly important within an introductory course created to demystify computer science for diverse students.

Yet what makes a "good" computer science teacher? While there is a dearth of academic literature describing the most effective computer science teaching practices, students had no difficulty describing excellent pedagogy. Unfettered by the claims and findings of educational research or learning theory publications, and speaking directly from the classroom experiences they were living in the moment, these high school students clearly expressed which teacher practices not only peaked their interests but also helped them retain new computer science concepts.

In what follows, "good" computer science pedagogy is defined via a comparison between students' most popular answers to the question "What do you think makes a good teacher?" and the classroom practices of Mr. Santos, Mr. Torres, and Ms. Mendoza. Themes emerging from student interviews were cross-checked with coding themes from observation field notes related

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to teacher actions that solicited deeper student thinking or engagement with discussions and computer science activities.

Subsequently, the descriptions of effective computer science pedagogy included in this chapter are organized according to students' definitions of "good" computer science teachers as those who: 1) are "easy to understand…doesn't over-complicate things" (Laura, C.Int4.5.17.12); 2) model processes "By showing examples…Like how you see it actually done" (Israel, C.Int16.6.4.12); 3) "interact with the student one-on-one" (David, P.Int2.5.7.12); 4) facilitate learning without telling the answers by "teach[ing] you, she doesn't do it for us" (Lena, M.Int2.5.10.12), 5) allow students to "team up with other people who understand it better" (Ruby, C.Int6a.5.3.12); and 6) support deeper thinking through carefully crafted questions. These pedagogical practices were key to making the intellectual rigor of computer science accessible to diverse learners.

The goal of this chapter is to describe shared pedagogy that worked, rather than describing individual teaching styles alone. While some of the unique qualities that make these three teachers special are lost as a result of my emphasis on common pedagogical philosophies and behaviors, this decision was a deliberate effort to challenge extant beliefs, namely that what happens in these classrooms cannot happen in other classrooms. When we observe strong teachers at work, it is common for people to be impressed at what they see without understanding how such pedagogy can translate to other educational spaces. We might say that a teacher was effective because of her or his individual personality, for example, or because their students seemed especially "gifted." However, while these three teachers had wonderful personalities, they were "wonderful" in very different ways that did not overlap. Furthermore, the students in these classrooms represented the diversity of learners we are likely to see in all

schools and were not all labeled as "special" or "gifted." The teaching methods that follow were chosen for their prevalence in *all three* classrooms with the belief that they can be translated into any other educational space.

Explaining Computer Science Concepts and Vocabulary

> "He explains the problems…he would either give you an example or rephrase the steps that we would have to take to pass the problem that we're facing." (Manuel, P.Int7.5.11.12)

Computer science is replete with acronyms, jargon, and ideas that can often feel alien and discomfiting to high school students or, in other words, that fit the contextual specificity of the students' lived experiences. However, a skilled computer science teacher knows how to explain new vocabulary or concepts in ways that students understand. This was true for all three teachers in this study. For example, Mr. Torres gave students a sheet of images that equated new html vocabulary to pictures representing students' personal interests: an html "header" was represented by a person hitting a soccer ball with his head, or in soccer terms, doing a "header" (P.FN.12.6.11). This assisted students in retaining new vocabulary. Ms. Mendoza, on the other hand, introduced new vocabulary more organically, pointing out terms in relation to ideas shared by students. For example, when a student described using *Google*, Ms. Mendoza immediately pointed out that *Google* was a type of "Search Engine." When students described using *Facebook*, Ms. Mendoza clarified that this was a type of "Social Networking" website. When students said they used *Wikipedia*, Ms. Mendoza explained that this was an "Open Source" website (M.FN.10.7.11). The effectiveness of this teacher practice when explaining new concepts was emphasized by an English Language Learner who said: "when she explains something, she gives you an example…even if she uses words that I don't really know because it's science—computer science—I still do get it" (Clara, M.Int7.5.11.12).

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Similarly, in an effort to demystify the way computers work, Mr. Torres helped students realize that they already understood "computer functions" because humans engaged in these same functions on a regular basis. Mr. Torres taught students that computers store data, retrieve/receive data, process data, and output data. Then, Mr. Torres compared this to what students do when completing a research project for school: students will retrieve/receive data about their research topic, process and store that data in their brains (the way a computer processes information in Excel or Microsoft Word), and then output that data in the form of a poster or essay (the way a computer might output data as sound coming out of its speakers) (P.FN.8.17.11).

On yet another occasion, while teaching students about binary numbers, Mr. Torres incorporated a kinesthetic method for making sense of 0's and 1's. Five students volunteered to stand at the front of the classroom, each holding a card with a specific number of dots in the following order: 16 dots, 8 dots, 4 dots, 2 dots, 1 dot. First Mr. Torres explained that these dots represented the binary number system into which text, video, mp3's, etc., get translated in order for computers to compute that information. Then he asked if students noticed a pattern in the number order. Students immediately recognized that they doubled from right to left. Then Mr. Torres had the students at the front of the room flash their cards in different configurations to represent different numbers that the class added up. He introduced the idea that when numbers show, they are "on" and represented by the number "1," and when the numbers do not show, they are "off" and represented by the number "0." After the class collectively added numbers and described their sequencing (e.g., When only the 2-dot card was visible, the total numeric value was "2" and the binary code for that value was "00010"), Mr. Torres asked various students to

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give the numeric and binary values for various other configurations of the cards at the front of the classroom. (P.FN.10.28.11)

The power of this method in teaching students binary became visible when Lissandro (who wasn't paying attention) struggled to compute the number and binary values in front of the class. Without waiting for Mr. Torres to reteach Lissandro, Belén quickly interrupted and taught him binary code in her own terms. When Lissandro floundered, Belén held up a binary card at the front of the room and pointed to her card dots, saying "This is on!" and then she flipped the card so no dots were visible and stated, "And this is off!" She flipped the card again so that the dots were visible and said "This is 1!" and then flipped it so no dots were visible and exclaimed, "And this is 0!" Her classmates giggled and smiled at her bright and quick demonstration, and when Mr. Torres asked Lissandro to try counting the number value and state the binary code of the card configuration again, he did so successfully without any further assistance. (P.FN.10.28.11)

These examples illustrate how translating computer science ideas in various ways that students can understand is a key pedagogical skill for effective computer science teachers. If teachers required that students memorize vocabulary lists without offering other ways of understanding new terminology or concepts, many students would have been left struggling to make connections to new learning.

Modeling Computer Science Practices

"He projects it on the computer, he does stuff step-by-step" (Malia, C.Int7.5.11.12)

Teachers facilitated learning by physically demonstrating how to perform computer-based tasks, preparing students to do their own projects using a similar—but not necessarily the

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same exact—approach[17]. For example, when exploring how computers could be used for visualizing data and art, Mr. Santos showed students how to create their own designs using a "virtual bead loom" from the Culturally Situated Design Tools website (http://csdt.rpi.edu/). Before using the software that required an understanding of the Cartesian coordinate system, Mr. Santos drew an x-y graph on the board with a point at (3,2) and asked students "What are the coordinates for this point?" He reminded students that: "x is the first, then y. Just like in your ABC's, x always comes before y." Students replied that the point was at (3,2). Then Mr. Santos directed students to the virtual bead loom website and projected the software program they would use on his whiteboard. Choosing a photograph of a real bead design to mimic digitally on the program, he drew an x-y coordinate system over the projected image of the design—with (0,0) falling on top of the yellow, center bead—so that students could see how each bead would represent a different point on the Cartesian plane. Noting, "think of every bead as one point," Mr. Santos asked students what the last black bead on the right would be on an x-y coordinate system. Hyun called out "(3,3)!" Mr. Santos then went into the software program and showed students how to place a black bead at the point (3,3) in the system in order to recreate the real bead design in the computer visualization program. Immediately understanding what to do after this demonstration, students started exploring the program on their own, creating bead designs in the software based off of real bead images. Mr. Santos encouraged them to find their own ways

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[17] Again, returning to my earlier comment that these descriptions of pedagogy draw on what was *similar* among the teachers in an effort to describe pedagogy that other teachers might also apply to their own classrooms, I would like to acknowledge the fact that pedagogy is as dynamic and fluid as the individuals that make up humanity. Reflecting for a moment on pedagogy as performance, I think it is useful to consider how a teacher's actions may be rooted in shared belief systems or understandings about the goals of practical pedagogical applications, but still appear individualized due to the way teaching is performed by each unique educator. Pedagogy as performance is what humanizes the teaching practice, making the act of education an art form that reflects the personality of the educator. As noted by Pineau (1994), "performance reframes the whole educational enterprise as a mutable and ongoing ensemble of narratives and performance, rather than a linear accumulation of isolated, discipline-specific competencies" (p. 10).

of visualizing designs on the computer, saying, "The choice is yours. Do it however you want…your way is fine" (C.FN.9.30.11).

Similarly, with a tower building problem solving activity—in which students had to calculate the shortest amount of time possible to build a 100 meter tower with 1-meter blocks when it takes a full week to lift any number of blocks onto another stack of blocks—both Mr. Torres and Ms. Mendoza modeled the process using books and Legos as building materials. At Presidential High, Mr. Torres brought five books to the front of the classroom and lay them all next to each other, explaining that each book represented a 1-meter block. He asked students how long it took to stack a single block on another, and they replied "one week." Then, Mr. Torres took the outer two books and stacked them on top of each other explaining that in one week with five blocks, he could complete two stacks of two blocks, and have a remaining block un-stacked as shown below:

Figure 5.1: Diagram showing how Mr. Torres moved the individual books to create stacks representing the tower-building process.

Next Mr. Torres explained "when week two comes up, I only have three stacks, so I can lift one stack on the other one" which he proceeded to do as follows:
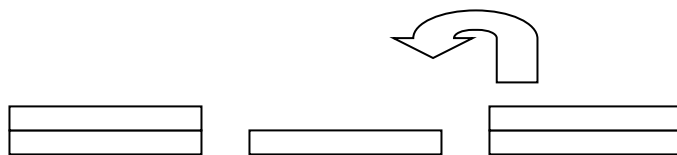
Figure 5.2: Diagram showing the next step of Mr. Torres's tower-building process with books.

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Finally, Mr. Torres asked what would happen during week three, and students recognized that only two stacks of blocks remained, so the job could be finished as shown below:
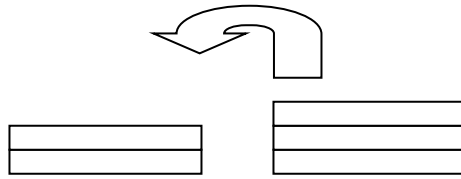
Figure 5.3: *Diagram of the final step Mr. Torres took to build a "tower" with the books.*

In this way, Mr. Torres modeled the problem-solving process for this activity so that students had some visual and tactile assistance when approaching a similar problem with a larger number of blocks (P.FN.11.2.11). As Ms. Mendoza explained when talking about learning to problem solve in computer science, "it's about the process, not the outcome" (M.FN.11.22.11). This was not an uncommon scene in the other two schools.

Teaching Students In Small Groups

> "If you have trouble, then he'll come and help you. And if he doesn't know it, then he'll work with you until you or him figure it out" (Olimpia, C.Int.13.5.30.12)

Neither Mr. Santos nor Ms. Mendoza ever sat down during class. Mr. Torres only sat down when troubleshooting network issues from his teacher computer. Indeed, all three teachers were constantly walking around their classrooms, engaging with students in small groups during activities if they weren't busy leading whole-class discussions from the front of the classroom. Students highly valued the ways their teachers gave them more individualized attention because it made computer science feel less intimidating and the projects more attainable.

For example, when learning about computer science algorithmic thinking, students were given a math problem in which they had to count the total number of handshakes occurring in a room where each of ten people must shake hands with another person but where no two people

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could shake hands twice. At City High, Theo, Peter, and Israel were working together and getting frustrated with the problem. Theo complained to Mr. Santos, "They're over-thinking it!" Mr. Santos smiled and asked what the group figured out so far. Israel explained that since there are ten people, then each person shakes nine hands, resulting in "9x10 = 90 handshakes." Mr. Santos asked why this was true and Peter noted that you can't shake your own hand. Mr. Santos replied, "But if you shake his hand, doesn't that count the same as him shaking your hand?" Peter widened his eyes and became pensive as Israel laughed, saying "That's what I was trying to say! Each time you shake a hand, it gets doubled…" The boys looked at each other confusedly, so Mr. Santos suggested "let's try a smaller number than ten and go up from there." Peter replied that if there were two people, then there would only be one handshake. Mr. Santos asked why and Peter explained that with two people, both shake hands and that counts as one handshake. Mr. Santos nodded his head in agreement and asked what happens with three people. Peter replied, "With three there are two…no three…" The boys paused and Israel said there seemed to be a pattern of "Even's odd and odd's even…" (referring to an even number of people resulting in an odd number of handshakes and vice versa). Since the boys still weren't certain, Mr. Santos suggested "let's try it here!" The three boys proceeded to try shaking each other's hands and counted three handshakes. Mr. Santos asked Israel, "Did your theory hold?" Israel said no and Mr. Santos said, "Well maybe keep trying it. See what happens with four people. You're on the right track here…draw it out or something." The boys smiled and eventually were able to figure out a pattern of decreasing handshakes over time resulting in a total of forty-five handshakes. (C.FN.10.17.11)

Mr. Santos continued to work with numerous students in the classroom this way not only during this activity, but all other activities during the school year. This quality of small group

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attention given to students proved useful for facilitating the thinking process through problems like the handshake activity described above.

Facilitating Learning Without Giving the Answers

> "He'll go along with you to fix it, not just kick you out of the seat and say [interviewee taps imaginary computer keyboard] 'There! I fixed it. Now continue.' Because then, after he leaves and if you run into the problem again, then if he's not there, you wouldn't know how to come to the solution he came to." (Ruby, C.Int6a.5.3.12)

Students across all three schools recognized that their teachers were effective at helping them understand and solve a computer problem without giving them the answers or doing it for them. Students appreciated this pedagogical method, which also worked well with teachers' practices of working with small groups of students.

For example during an algorithmic thinking problem, Clara at Presidential High was trying to figure out how long it would take to build a 100-block building if you had an unlimited number of block-lifters, but could only stack two blocks at a time each week. She had almost solved the problem, but noticed her blocks were not adding up to 100. Mr. Torres looked at her drawing where she had begun by creating fifty stacks of two blocks during the first week, then twenty-five stacks of four by the second week. He asked her "During week three, what happens?" She explained she had six stacks of twelve, with a leftover four blocks. Mr. Torres said "Something's missing because that doesn't add up to 100 but only to seventy-six." He backtracked to week two and asked how many blocks Clara had, and she noted twenty-five stacks of four which add up to 100." Mr. Torres asked what happened next, and Clara explained, "then you make twelve stacks of eight because you can't cut twenty-five into a perfect half. There are leftover blocks." Mr. Torres replied, "Okay, so 12x8 = 96 with four leftover. So what about week four?" Clara said she would have six stacks and Mr. Torres asked "of what?" Clara

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replied "twenty-eight." Mr. Torres then asked what happened if you double the number eight. Clara said you get sixteen. Mr. Torres asked what happened if you double sixteen and Clara paused. Widening her eyes, Clara recognized her mathematical error and that she was calculating 16x2 as 28 instead of 32, resulting in the "lost blocks." Mr. Torres asked, "So you understand?" and Clara smiled, exclaiming "Yes!" (P.FN.11.2.11). Without telling Clara exactly where her error occurred, Mr. Torres helped walk her through the problem to see an answer on her own.

At City High, when Alejandra was trying to create a computer visualization of an African American cornrow hairstyle, she was unsure what the mathematical term "translation" meant on the software program. Instead of giving her the definition, Mr. Santos asked, "If you enter the number fifty, what does it do?" Alejandra entered the number fifty into the software program for "translation" and noticed that the image became larger as the cornrow braids spread apart. Mr. Santos asked her what happens when she tried a smaller number like twenty-five. Alejandra changed the translation number to twenty-five and remarked that it became smaller. Mr. Santos asked by how much and Alejandra explained "one-half, because twenty-five is half of fifty." Mr. Santos replied, "Exactly! So what is that tool?" Alejandra said, "the space got bigger or smaller, so they [the braids] get closer." Through this process, Alejandra was able to figure out the meaning of "translation" on this software program without Mr. Santos telling her the definition directly (C.FN.10.5.11).

When working with a Special Education student named Melissa while learning how to analyze snacking data collected by students in the MyData data analysis unit, Ms. Mendoza never told Melissa what to think about the data, but instead helped her interpret a graph. Melissa had created a graph showing how many snacks fell in each of the health levels (with health level "1" being the least healthy and health level "5" being the healthiest). Ms. Mendoza asked

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Melissa what the graph showed, and Melissa said she didn't know. So Ms. Mendoza pointed to the x-axis and noted that this marked the health levels (1-5) and then she pointed to the y-axis, explaining that it showed the number of surveys/snacks. Then Ms. Mendoza asked, "So which kind of snack did we eat the most of?" Melissa eventually pointed to the tallest bar on the graph. Ms. Mendoza smiled, nodded her head in agreement, then said while pointing to the health levels from 1-5 respectively on the x-axis, "So if this is really unhealthy, unhealthy, middle, healthy, and really healthy…what do you think people were eating mostly?" and Melissa paused, struggling to understand. Ms. Mendoza then pulled out a hand-drawn graph that Melissa created the previous week and said "I have your graph from last week" and they looked at it. Melissa still wasn't sure what people ate—mostly healthy or unhealthy snacks, so Ms. Mendoza encouraged her saying, "It's hard, right? Because you can't see the break down…" After which Ms. Mendoza returned to Melissa's graph on the computer screen and, pointing to the 1 and 2 health levels, she noted "So this side is unhealthy" and then pointing to the 4 and 5 health levels, she explained, "And this side is healthy." Then Ms. Mendoza said, "So let's do the numbers!" Taking out a piece of paper and pen, Ms. Mendoza asked Melissa to give her the total number of snacks in the "very unhealthy, level 1" section. Melissa looked at her bar plot and said, "31." Ms. Mendoza wrote this down and asked for the total in the "unhealthy, level 2" section and Melissa counted "30." After doing this for all the levels, Ms. Mendoza had Melissa count the total number of snacks in the very unhealthy and unhealthy sections, then the very healthy and healthy sections, to compare the totals. In this way, Melissa began to learn about how to compare the snack data sets and draw a conclusion about trends in snacking habits without Ms. Mendoza telling her exactly what to think about the graph. Melissa learned more about the data analysis process this way, rather than focusing on the answer alone. (M.FN.5.29.12)

Supporting Peer-to-Peer Learning

"[The teacher] makes people be focused on the subject, make them interact more with each other…telling you how to work with your partners: 'If you don't understand, ask them. Then ask me.'…It's pretty nice how he does that. Not other teachers do that because they would complain, 'Why are you talking in class?'" (Israel, C.Int16.6.4.12)

Students in all three classrooms appreciated their teachers' support of peer-to-peer learning. Some recognized its value for building new friendships, while others mentioned that it was more efficient to turn to a classmate for help when teachers were busy. Yet, peer-to-peer learning was only possible because these computer science teachers valued their students' knowledge and ways of thinking. Furthermore, these computer science teachers understood that peer-teaching could positively impact student learning by encouraging students to reflect on what they just learned while teaching it to a friend. As Mr. Santos once stated, "if you can't explain it, then you don't understand it" (C.FN.9.1.11).

Thus, teachers supported peer-to-peer learning in a number of ways. For example, in the same handshake activity described above, Olimpia and Ian were working as a team. However, Ian just sat there as Olimpia solved the problem alone. When Mr. Santos walked by and asked the team to explain their answer, Olimpia showed him the back of her journal where she had drawn out a table where each letter of the alphabet from A-J represented one of the ten people in the room. She counted the total number of handshakes based on this table as shown below:

	A	B	C	D	E	F	G	H	I	J
A		1	1	1	1	1	1	1	1	1
B			1	1	1	1	1	1	1	1
C				1	1	1	1	1	1	1
D					1	1	1	1	1	1
E						1	1	1	1	1
F							1	1	1	1
G								1	1	1
H									1	1
I										1
J										

Figure 5.4: Recreation of the grid Olimpia drew to count the number of handshakes in the problem-solving activity.

In this table, Olimpia made sure not to double-count handshakes between individuals or handshakes made with oneself. Mr. Santos congratulated Olimpia on her work, then pushing her to think more deeply about the algorithm behind this problem, he asked her how many handshakes would happen if there were twenty people. Olimpia said quickly, "190." Mr. Santos asked how she came up with this, and she showed him another sheet where she drew out the same kind of table with more individuals. Mr. Santos turned to Ian and asked "See how she did it?" Ian shook his head "no." Instead of explaining Olimpia's process himself, Mr. Santos asked Olimpia to explain it to Ian. Olimpia pointed to her first table and said, "Okay, so there's ten people. Person A shakes hands with Person B…" and she pointed to the handshake marked in the table. "Then Person A shakes hands with Person C…" and she pointed to this handshake on the table as well. Olimpia continued this way until Ian interrupted saying, "I get this one, but not the other one." So Olimpia pulled up the other table and said, "It's the same idea. This person shakes with each person in the group of twenty people, then the next person shakes hands with everybody else and doesn't include himself and the first person, etc." Ian's eyes widened in

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understanding and he said, "Oh, I see" (C.FN.10.17.11). Mr. Santos's support of peer-to-peer learning gave students the ability to practice explaining their thinking aloud, reinforcing new learning through peer-teaching while being informally assessed by the teacher.

Interestingly, over the school year students began to improve their own teaching skills with one another, mimicking their teachers' ways of assisting students one-on-one. In other words, students stopped telling each other the answers to questions and facilitated their classmate's learning with supportive questions instead. Such peer-to-peer teaching practices required a deeper understanding of the material while engaging important metacognitive skills. Consider, for example, how Juliette assisted Annie in making sense of a graph made with student snacking data in Ms. Mendoza's classroom. After Julio taught Annie how to create a pie chart of snack health levels using the JGR/Deducer data analysis program, Juliette turned to Annie and asked, "So what can you say about this chart?" Annie replied, "They're the healthy levels." Juliette replied, "Right. So you can see that each level is kind of equal…" Annie nodded her head as Juliette then added, "So we can't really say that we're eating healthy or not healthy" (M.FN.6.6.12). What's notable about this moment was the way that Juliette chose to assist her friend, Annie. Normally, one would expect a student to say the answer immediately without giving their classmate a moment to think about it. It is often assumed that when a classmate asks for help, she or he is asking for the answer to a question and not help with *thinking through* the question. And while Juliette eventually presented her own interpretation of the pie chart, she did so *after* asking Annie to try to make sense of it first. Furthermore, Juliette posed her question to Annie about the pie chart in a way that Ms. Mendoza might have asked it, reflecting how she supported her classmate's analytical thinking before offering an answer. While one might say that Juliette could have waited longer for Annie to figure out the pie chart on her own, the fact

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that Juliette gave Annie a chance to reflect at all shows a deeper thinking process about data analysis and peer-to-peer learning in this classroom.

Asking Effective Questions That Deepen Student Thinking

Indeed, the ways teachers asked questions (influencing how students asked each other questions as with Juliette and Annie above) proved crucial to supporting student learning in computer science. All three teachers regularly questioned their students' ideas in order to help them think "outside the box." For example, in a lesson introducing students to the idea that "data are everywhere," students were asked to make a list of items (data) visible in a drawing of a person in a room. Through this process, many students' assumptions about this person and the room began to surface, revealing the ways people go through an *interpretation* process when making sense of data. In this activity at City High, Ruby had decided that the person in the room was a boy. Mr. Santos asked "Why?" Ruby paused and said, "because of the baggy jeans…" However, at second glance, Ruby decided, "but it looks like a girl because of the bangs," referring to the person's hairstyle in the drawing. Mr. Santos smiled and noted "But I've seen lots of women wear baggy jeans," then he added that the hair might reflect the person's fashion sense, asking "And what if it's a punker-guy?" Ruby laughed, recognizing the mistake of her assumptions and Mr. Santos asked, "So what are you looking for to help you decide [the person's gender]?" Ruby mentioned, "it's kind of a unisex room because it has stuff in there that a boy and a girl would have…" In this exchange, Mr. Santos pushed Ruby to reconsider her assumptions about the person in the drawing based on the data at hand, urging her to be cautious about the conclusions made from the person's fashion sense or the objects in the room. (C.FN.9.26.11)

At Midtown High, Ms. Mendoza also phrased her questions to encourage deeper student thinking. Reflecting on the ways personal information is made available through peoples' use of the internet, Ms. Mendoza asked, "What does *Google* know about you if you're searching from a Starbucks? What does it tell them?" Students called out that they know you like coffee. Ms. Mendoza urged her students to think more creatively, asking "Yes, but what else can they assume? Maybe you're wealthy because you have a lot of extra time and money to be sitting at a Starbuck's in the middle of a Tuesday afternoon?" This encouraged a student to probe more deeply and reply, "Or maybe you're unemployed!" Another student joked, "And lonely!" Ms. Mendoza laughed with her students and added that you could also be retired. Then another student pointed out that *Google* would learn your web-browsing history as well. Through her questions, Ms. Mendoza facilitated critical thinking around "data that they use to determine what to show you" on *Google* as well as the "various ways data limits what we find when we research." (M.FN.10.11.11).

Conclusion

The examples above describe what was typical in the three computer science classrooms of City, Presidential, and Midtown High Schools. These pedagogical practices (explaining ideas and vocabulary, modeling processes, supporting small groups of students, facilitating learning without telling the answers, encouraging peer-to-peer learning, and asking questions that push student thinking) not only emerged as common themes in effective teaching through classroom observations, but also were directly identified as important by students across all interviews.

While these methods proved effective for teaching computer science concepts and computational thinking skills—such as algorithmic, abstract, or recursive thinking in technology-based problem-solving contexts—two other pedagogical practices emerged in the three

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classrooms as the school year proceeded. These teacher practices may not be directly relatable to computational thinking skills in the ways that modeling a problem solving process might, but rather, these two emergent practices humanized computer science, thereby engaging students in valuable ways. The two teaching methods that made computer science more accessible to diverse learners were: 1) what I define as a "Connected Computer Science Pedagogy" that related to students' personal interests, linked academic learning to real social issues, and supported collaboration, and 2) infusing humor into computer science lessons. I have chosen to describe these pedagogical practices with greater detail in the pages that follow because studies of computer science pedagogy that connect to students' personal interests, social issues, and humor are rare. These next chapters offer a firm base upon which we can explore a more humanizing computer science pedagogy that can reach a broader spectrum of diverse learners.

CHAPTER SIX
Connected Computer Science Pedagogy:
Connecting Computer Science Learning to
Students' Personal Knowledge and Real Life Issues

"Making this accessible to them is really important to me, because this is the first step to getting more people of color in the sciences." (Ms. Mendoza, M.T.Int2.6.14.12)

Introduction

In a lesson introducing the various ways data can be represented and interpreted, Ms. Mendoza explained to her high school students that people generate data all the time whether they realize it or not. She proceeded to share a list of websites that she had visited over a 24-hour period as an example of data created in one day. Ms. Mendoza asked students what they might conclude about her from this list. Larry mentioned: "You like gadgets because you visit gizmodo.com a lot!" Ms. Mendoza agreed this was true. Then Julio called out "you like *chisme*[1] because you visit gawker.com a lot too!" Everybody laughed together. Ms. Mendoza continued, "And what *doesn't* it tell you about me?" Students called out "Your birthday! Your race! Where you're at!" Ms. Mendoza nodded her head. Then, while agreeing that her race was unclear, she asked students what race they might guess she was. Natalia mentioned that she "seemed White." Ms. Mendoza [who is Latina] asked why and Natalia replied, "Because of the websites you go to. A lot of them have to do with computers." Ms. Mendoza asked the entire class: "Why is it that we associate being White with knowing a lot about computers?" Albert raised his hand and said, "I don't want to be racist, but…" and Ms. Mendoza cut him off, saying with a smile, "Whenever somebody says that 'they don't want to be racist,' it means that they will most likely say something racist." Albert laughed in agreement and decided to make his point anyway, saying: "Most computer geniuses are White." Several students nodded their heads. Ms. Mendoza raised her eyebrows and asked: "Then what are we doing here [in a computer science class]?" Albert replied quickly, "Not being White." After everybody giggled together and the room became quiet again, Ms. Mendoza beamed at her students while saying in a serious tone, "So look around this room. We're all people of color. We're trying to break the stereotype." (M.FN.10.18.11)

Computer science is dominated by White men and certain sub-groups of Asian men (National Center for Women in Technology, 2012). The vignette from Midtown High above suggests that teenagers of color are often cognizant of this fact and, as a result, may not typically envision themselves fitting into such a field. Being a technology enthusiast seems like a "White"

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[1] *Chisme* means "gossip" in Spanish.

thing to be, suggesting that the world of computer science is inaccessible to Midtown High's students of color before they even know how to define computer science.

What's interesting about this vignette, however, is not the pervasiveness of racist stereotypes regarding who should love and excel with technology. But rather, I want to draw attention to the teacher's expert way of both acknowledging and challenging students' stereotypical beliefs about technology-users by encouraging students to change perceptions about race-based abilities through *their own* identities and actions.

Four aspects of the above vignette help support this argument. First of all, Ms. Mendoza made important connections between computer science and real life, using her own list of websites visited over twenty-four hours as a springboard into discussions about data. While students typically experience "data" in school only as numbers on a spreadsheet, Ms. Mendoza taught her students that data in computer science and the real world are not limited to mere numbers, but also can be found in the accumulation of URL's visited throughout a day. Furthermore, Ms. Mendoza encouraged her students to make sense of what such data (this list of websites) might reflect about the technology-user (herself). In this way, students began to seek patterns and draw tentative conclusions about Ms. Mendoza based on the data list. The relationship between the social world and computer science began to surface through this exercise.

Secondly, Natalia's honesty in questioning Ms. Mendoza's racial identity by stating that she seemed "White" because of the websites she visited, as well as Albert's openness in stating what may be interpreted as "racist" suggest that students viewed this classroom as a safe space. One could imagine students and teachers often shying away from these topics of discussion in an effort to avoid conflict in the classroom. However, Natalia and Albert recognized that their

words would not be condemned, and thus they were willing to question Ms. Mendoza's race as a Latina. Rather than be offended by students' racial judgments of her behavior, Ms. Mendoza embraced her students' responses by asking them to explain their reactions. In this way, Ms. Mendoza supported the sense that students can be open and safe in the classroom, while also encouraging their analytical skills in verbally defending their ideas.

Thirdly, Ms. Mendoza urged her students to be careful about the conclusions they made based on her technology-use, asking students about what they both could and could not conclude. Ms. Mendoza used the connection between real life computer use and data in computer science to teach students how to think critically about the information provided. Rather than just accept this data at face value, students were encouraged to question what the data could and could not express about the computer-user.

Finally, Ms. Mendoza was able to question students' perceptions of race and computing by placing a mirror before them while helping them understand how they, as students of color, have the power to challenge stereotypes about who is allowed to love technology or excel with it. After accepting her students' reactions, thereby validating the ideas they wanted to share, Ms. Mendoza helped students realize that they had the power to change how the world perceives them.

Why are these four actions—1) connecting computer science to real life, 2) embracing students' perspectives and experiences with technology, 3) questioning social narratives developed from data lists, and 4) drawing on such perspectives/experiences to challenge beliefs about computer science—important in a computer science classroom? Shouldn't students only focus on algorithmic thinking or just the data itself? Why connect computer science to the social world if the real goal is problem solving or programming?

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Pedagogical Frameworks for Rethinking Computer Science Pedagogy: Critical Pedagogy, Culturally Relevant Pedagogy, and Connected Learning

To answer these questions, let us return to the overrepresentation of White and sub-groups of Asian men in computer science.

Females and students of color often feel unwelcome in the field of computer science because of the way it is taught in educational institutions (Margolis & Fisher, 2003). For example, young women at Carnegie Mellon University revealed that they were neither disinterested nor unable to succeed in computer science, but rather that computing culture had been presented to them as a "male" field, leading to "a narrowing of girls' and women's options, and often to the extinction of their nascent interest" (Margolis & Fisher, 2003, p. 144). Many women who might have pursued computing careers described feeling alienated by a computer science environment that was "not made for them" (Margolis and Fisher, 2003, p. 144). Women wanted to learn about "computing with a purpose" in a way that connected computer science with real life issues instead of just programming for programming's sake (Margolis & Fisher, 2003; Fisher, Margolis, & Miller, 1997). In university computer science courses, an overemphasis on skills such as memorizing programming language rather than illuminating the larger social purpose of programming deterred women from pursuing this field of study.

Similarly, in an examination of three urban public schools, Margolis et al. (2008) found that students rarely had access to rigorous computing courses and, when they did, the curriculum felt inaccessible or boring. Students who had the potential to engage with computer science were immediately put off by courses that failed to connect their curiosity about technology to its social context (Margolis et al., 2008).

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These findings emphasize that women and students of color weren't necessarily *disinterested* in computer science or *unable* to excel in the field, but rather they were denied opportunities to learn computer science in meaningful ways.

Recognizing that STEM fields like computer science have been failing to attract young women and students of color because of the way ideas were taught and presented, a handful of STEM projects have begun to design curricula and instruction around the perspectives and interests of their diverse students. This approach has had positive results. For example, the COMPUGIRLS program in Phoenix, Arizona is a two-year-long sequence of courses for high school girls that teaches computational thinking through culturally relevant activities geared toward developing students' positive self-concepts in computing. Teachers are trained to help students identify topics of interest through their own lived experience (called "reflective action"), build on students' topical knowledge to explain its importance in relation to a social justice issue ("asset building"), and teach students how to report on their experiences with these computing projects in relation to the larger social community ("connectedness") (Scott et al., 2010). This approach to teaching computer science by building on students' personal interests and drawing on their perspectives has resulted in valuable engagement and increased interest in computing for the young women of color in this program.

Similarly, the Female Recruits Explore Engineering (FREE) program identified 131 10th grade girls with strong academic records in math and science at seven high schools in Colorado, Iowa, and Ohio. The majority of these young women were students of color qualifying for free/reduced lunch at school. Through a program that focused on relating engineering learning to girls' personal identities, over half of the program participants began considering majoring in engineering in college (Eisenhart et al., 2010). Encouraging interest and persistence in

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STEM/technology-oriented fields was not difficult when the curriculum and pedagogy made learning relatable to diverse students' personal lives and interests in social justice. Computer science classrooms could learn a lot from the culturally relevant efforts of these out-of-school spaces.

Of course, the value of relating learning to students' everyday lives while drawing on the knowledge and skills students already have is not a new concept. Many have described the power of this work through "critical pedagogy" (e.g., Apple, 1990; Freire, 1970; Giroux, 1997; McLaren, 1998, 2003, 2005; Morrell, 2008), "culturally relevant pedagogy" (e.g., Gay, 2010; Ladson-Billings, 1994), and teaching that draws on students' "funds of knowledge" (e.g., Moll et al., 1992; Moll & Ruiz, 2002). For example, critical pedagogy is rooted in the idea that:

> Education as the practice of freedom—as opposed to education as the practice of domination—denies that man is abstract, isolated, independent, and unattached to the world; it also denies that the world exists as a reality apart from people. Authentic reflection considers neither abstract man nor the world without people, *but people in their relations with the world.* (Freire, 1970, p. 62, emphasis added)

As such, proponents of critical pedagogy argue for engaging students in linking academic learning to their lived realities, supporting students to grow through a conscientization process of examining the world and questioning all unethical power hierarchies in relation to the written word. Similarly, culturally relevant pedagogy—also described as "culturally responsive teaching"—respects students' cultural diversity from varying ethnic backgrounds and alters teaching methods to validate cultural knowledge/skills/beliefs as strengths by drawing on them as resources, thereby empowering students to embrace their cultural identities in schooling spaces (Gay, 2010; Lipman, 1995). The goal is to "empower students intellectually, socially, emotionally, and politically" through references to students' cultural practices and beliefs (Ladson-Billings, 1994, p. 17). This is also true for teachers who draw on students "funds of

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knowledge," showing a willingness to learn from students and their families to find where home

knowledge/skills/beliefs can support academic content or lessons (Moll et al., 1992; Moll &

Ruiz, 2002). Though these approaches have important differences, they share a concern with

empowering students through educational experiences that validate students' diverse

perspectives and knowledge toward positive social change.

Reflecting many of the same ideas described in critical pedagogy, culturally relevant

pedagogy, or funds of knowledge, a group of researchers, designers, and practitioners seeking to

ensure equitable learning opportunities in the digital age recently developed what they call

"Connected Learning" (Ito et al., 2013). As noted by Ito et al. (2013), this model of learning "is

less a 'new' approach to learning than it is an ongoing effort to draw linkages between existing

approaches that share a set of core values and goals" (p. 22). More specifically, connected

learning:

> Advocates for broadened access to learning that is *socially embedded, interest-driven,*
> *and oriented toward educational, economic, or political opportunity.* Connected learning
> is realized when a young person is able to pursue a personal interest or passion with the
> support of friends and caring adults, and is in turn able to link this learning and interest to
> academic achievement, career success or civic engagement. This model is based on
> evidence that the most resilient, adaptive, and effective learning involves individual
> interest as well as social support to overcome adversity and provide recognition. (p. 3)

Rooted in the same sociocultural learning theory upon which my own dissertation study is built,

connected learning focuses "on supports and mechanisms for building environments that connect

learning across [students'] spheres of interests, peer culture, and academic life" (Ito et al., 2013,

p. 3).

Ito et al. (2013) developed a framework for understanding what connected learning looks

like through both in-school environments such as Quest to Learn, an innovative New York City

school, and out-of-school contexts such as the Harry Potter Alliance, a nonprofit organization

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that draws on youth fan culture to drive civic engagement. This framework outlines: 1) key features of connected learning contexts (peer-supported, interest-powered, and academically oriented); 2) core properties of connected learning experiences (production-centered that is openly-networked with a shared purpose); 3) design principles informing the intentional connection of learning environments (where everyone can participate, learning happens through doing/making, challenges cultivate interest, and all contexts are interconnected); and 4) the new media used to amplify connected learning opportunities (by fostering engagement and self-expression, increasing accessibility to knowledge and learning experiences, expanding social supports for interests, and expanding diversity and building capacity) (Ito et al., 2013, p. 8).

Considering the successes of culturally relevant STEM programs like Compugirls or FREE, as well as students' academic achievements within Quest to Learn or the Harry Potter Alliance connected learning environments, it is not surprising that the importance of relating school learning to students' everyday lives and interests also emerged out of the three classrooms I focus on in this dissertation.

Interestingly, the ideas developed through critical pedagogy, culturally relevant pedagogy, funds of knowledge, and connected learning are still new to the field of computer science education. Furthermore, Mr. Torres, Mr. Santos, and Ms. Mendoza taught in ways that reflected these pedagogical approaches even though they did not name their teaching practices as such. Through both word and action, all three teachers and even their students emphasized that "good teaching" involves helping students see a connection between academic learning and their personal interests or knowledge, while also empowering students to be able to address real social issues in their communities. Similar to the pedagogical values running through critical pedagogy or connected learning, these three dissertation classrooms demonstrated how students wanted to

learn computer science when they could directly apply such learning to improving their real lives.

Yet the idea that computer science can be taught in relation to students' out-of-school lives or social change is rarely discussed in academic literature. While several inspirational programs are currently engaging new media technology toward civic engagement—consider, for example, the efforts of Chicago's YOUmedia and the Digital Youth Network that teach digital literacy with new technology—few of these projects relate specifically to computer science and only a handful take place within traditional schooling contexts. And while the connected learning movement's agenda is "complementary with many progressive and equity-oriented reform efforts in school and policy arenas" they "do not focus primarily on the formal educational system in [their] work" (Ito et al., 2013, p. 21). Furthermore, we lack terminology for the kinds of teaching practices in computer science education that emerged in my dissertation classrooms. This may be due to the fact that computer science is a fairly new academic field (in comparison to science, math, and history) and that teaching with computer technology seems to be in a constant state of flux as new tools develop faster than they can be incorporated into school spaces.

As such—and for the sake of encompassing all of the rich pedagogical tools described in critical pedagogy, culturally relevant pedagogy, funds of knowledge efforts, and connected learning—I propose using a new term to refer to the computer science pedagogy that was practiced in Midtown, Presidential, and City High Schools: "Connected Computer Science Pedagogy (CCSP)."

Connected Computer Science Pedagogy (CCSP)

Connected Computer Science Pedagogy (CCSP) emerged as an important theme through both interviews and classroom observations. Codes that focused on describing pedagogy developed through multiple readings of field notes, interviews, and surveys (e.g., "Connections to real life," "Offers tips for life/economics and job opportunities," "Asks for student opinion or personal perspective," "Builds off student input/understanding or accepts student input," "World Issues, school-related issues, social issues," "opportunities for social change") and reflected many important ideas related to critical pedagogy, culturally relevant pedagogy, funds of knowledge, and connected learning. More specifically, direct linkages can be made between teacher pedagogy that engaged students in learning computer science in the dissertation classrooms and connected learning's "three crucial contexts for learning" described in the diagram below:

Peer-supported: In their everyday exchanges with peers and friends, young people are contributing, sharing and giving feedback in inclusive social experiences that are fluid and highly engaging

Interest-powered: When a subject is personally interesting and relevant, learners achieve much higher-order learning outcomes

Connected Learning

Academically oriented: Learners flourish and realize their potential when they can connect their interests and social engagement to academic studies, civic engagement, and career opportunity

Figure 6.1: *Connected learning's crucial contexts for learning (Ito et al., 2013, p. 8).*

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Indeed, patterns in teacher practice that resulted in meaningful student engagement, i.e., high participation in group discussions and computer science activities, clearly reflected the three crucial contexts for learning of connected learning. More specifically, all three teachers showed efforts to be 1) "interest-powered" by relating to students personal interests; 2) "academically oriented" by connecting learning to civic engagement and real social issues of interest to students; and 3) "peer-supported" by providing opportunities for students to share and give feedback in collaborative efforts.

While connected learning is useful for understanding core properties of meaningful learning with new technologies, Mr. Torres, Mr. Santos, and Ms. Mendoza's pedagogical practices (described as CCSP) explain *how* such connected learning contexts can be organized in computer science classrooms. CCSP uses connected learning as a springboard to explain how "crucial contexts for learning" can be created through specific pedagogical practices. I am interested in how connected learning contexts come to be in computer science classrooms. Thus, CCSP describes *what* teachers can do to make computer science learning interest-powered, academically oriented, and peer-supported.

In what follows, I will describe the "what" and "how" of CCSP as developed through educators' and students' definitions of "good" teaching, as well as through observations of common teaching practices that effectively engaged students in computer science learning in the three dissertation classrooms.

CCSP: Making Computer Science Personally Relevant While Validating Students' Perspectives

All three teachers regularly drew connections between computer science content learning and students' everyday lives. As Mr. Torres at Presidential High explained, students "need to know what's the point" because they're always asking "'Why?...Why are we learning this?' So if

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you don't show them that, I don't think you're going to get the amount of effort and dedication that you would normally" (P.T.Int2.5.29.12). Mr. Torres explained that this was particularly important for computer science classrooms that must keep pace with ever-evolving technological tools. He made it a goal to help students "see that they're surrounded by [technology], their everyday lives" because lessons could be made more "poignant" as students see the connection between daily life and computer science class: "they're so reliant upon their phones. That's a big hook right there, you know?" (P.T.Int2.5.29.12). Similarly, Mr. Santos explained, computer science class needs to make connections to life beyond the classroom because "It has to do with social issues…the way humans interact and see the world" (C.T.Int2.6.4.12). Equally important is the need to invite students' diverse perspectives rooted in real life experiences as Mr. Santos noted, "[I] try to get a balanced approach to new ideas and present it different ways…letting them know that *all* of us have something to contribute to whatever it is that we're doing" (C.T.Int2.6.4.12).

Ms. Mendoza echoed Mr. Santos's belief that computer science learning should relate to students' lives outside of school by respecting all students' voices in the classroom:

> [My class] is definitely about making computer science available to all students, and one of those things is to break down the gender barrier and the race barrier. So when my students bring those "isms" [racism, sexism, etc.] into my classroom, it doesn't have any place here…one of the first things I started doing is when the boys would talk over the girls, I would be like "Hey, let her finish! Why do you feel like you have to finish her sentences?" Because as a woman, I know how that feels…it makes us feel very weak, it makes us feel disengaged, like we don't have any power. And it starts in the classroom for me. (M.T.Int2.6.14.12)

Again, while the teachers did not necessarily describe their practice as rooted in critical or funds of knowledge, their intentions reflect a desire to build off students' diverse perspectives and address unequal power relations in their classrooms in important ways. All three teachers shared the belief that computer science should be made accessible to all students by relating the

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coursework to real life while acknowledging the diverse ideas, voices, and perspectives of students.

While these teachers never made their pedagogical approaches explicit to their students, students voiced that they highly valued their teachers' methods of relating computer science to real life and validating all students' perspectives. As Darrel at City High explained:

> The best teachers are the ones that can take what's in the classroom and really apply it to you…how is this going to help me in the future?...and I would consider this class being one of those…where I feel like the application is really going to the real world. (Darrel, C.Int2.5.30.12)

Darrel's classmate Carlos agreed: "if we just talk about the technology, then people might not be so much interested in it. But when you talk about technology and then try to relate things to it, then you start feeling like, 'huh, what's technology doing to *me*?'" (Carlos, C.Int1.5.9.12). James added:

> You walk into a class with the subject on the door…you'd expect, 'oh, we're only going to talk about this.' But him talking about his personal life, him asking about ours, and him just bringing [in] the whole world…because technology *is* the world…you'd never think you'd think so deeply in a computer science class. You know, usually people come in and they think 'okay, I guess I'll just learn how to type and, you know, make cool looking pictures'…But no. Actually, it's a lot more deeper than that. (James, C.Int.3a.5.14.12)

The majority of students at all three schools agreed that relating computer science to real life was valuable for a number of reasons. First of all, it made the subject more accessible as students stated: "you see how it's used outside, and you see how real things are going on in the world and it's a lot easier to figure out stuff" (Lisa, C.Int4.5.17.12); "If he relates it to me, then I feel like, 'oh I could do it then.' And it makes me motivated" (Hyun, C.Int14a.5.7.12); "[he makes it] easier for us by giving us examples that we know about…it's something we can relate to" (Isaac, P.Int4a.5.23.12); "It makes it easier because then you can relate to that…since you already lived it, it's easier to understand what you're doing" (Annie, M.Int10.6.1.12).

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Secondly, students felt that connecting computer science to real life motivated them to learn: "if your teacher relates it to life, then I guess people become more interested…because we think, like 'oh we might use this'" (Juliette, M.Int3.6.8.12); "I don't like to just be on the computer and then talk about how it is and everything. I want it to be something that relates to life skills" (Belén, P.Int6.5.9.12); "when you feel like the teacher is relating the topic about you and everything in life, you actually learn something and you're actually interested in doing the work" (Allison, P.Int16.5.8.12); "if you teach something that's not in [students'] interest, then they don't like coming to class or doing the work" (Annie, M.Int10.6.1.12).

Thirdly, the majority of students felt that seeing connections between real life and computer science helped them think beyond life after high school. As Manuel explained, he used to think computer science involved only typing or using a search engine, but "Now I notice it's not even about that. You put *science* in it too" which has helped him find "goals" in life to be a computer science teacher like Mr. Torres (Manuel, P.Int13a.5.9.12). Similarly, Lena believed Ms. Mendoza's way of framing computer science in relation to real life was exciting because she was "Not only learning stuff, but knowing the fact that you can get a career in that" (Lena, M.Int2.5.10.12).

When asked to describe what "connecting to real life" looked like in their computer science classes, students offered rich responses that emphasized how merely drawing relationships between technology and real life wasn't enough. Many students described wanting their perspectives about life validated in relation to computer science learning in ways where the teacher "gives his opinion and he let's us give our opinion too" (Julieta, P.Int10.5.11.12). David described that Mr. Torres did this in a specific and artful way:

> Almost every day when we come into the class, before he gives the lessons, before we talk about what we're doing, he always opens up to us…Like 'Hey, how's it going…' we

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start talking about, maybe if he heard something in the radio…that gives me the 'okay.' Like if I heard something, maybe I can speak out and let him know. And I've done it three, four times…he gives an opportunity for us to bring a topic from outside the class. (David, P.Int2.5.7.12)

For David, this added to his sense of belonging in the computer science classroom, but also helped him feel that computer science was something relatable to his everyday life. Notice how David described Mr. Torres's method of "opening up" in computer science class, talking about a radio show and welcoming students to also share what they've heard or know. In this way, David suggested that his perspectives were welcomed and validated, showing a connection between computer science class and the everyday.

Other students described enjoying specific projects because their teachers encouraged them to relate computer science learning to their personal lives. For example, Belén at Presidential High enjoyed creating an animation project not only because it related to her love of film, but also because it helped her reflect on opportunities to pursue this area of expertise as a career. Mr. Torres's suggestion to draw a storyboard the way TV animators do engaged Belén in her project process:

I like film and all that stuff, and he told me do a storyboard like a short….it kind of helped me because it's like: "Do I really want to do this and why not?" And it tells me how it would taste to do that and am I thinking I kind of like it. You know, you could practice doing it on the computer. (Belén, P.Int6.5.9.12)

Here, Belén described how playing with animation in computer science gave her a chance to "practice" something she may want to do after high school. Similarly, Samson at Midtown High felt that his love of sports could shine in his computer science class because of the ways his teacher connected computer science learning to his personal interests. As a result, Samson recognized that he could apply his computer science learning around data to his athletic life, noting that it could help him analyze his strengths and weaknesses during a sport season: "for

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sports, they could get the data and…I could get how many points or how many goals I made in the past year, what has helped me, what hasn't…" (Samson, M.Int4.6.1.12). Along the same vein, Manuel at Presidential High loved creating a Powerpoint about his own life and felt greater confidence about being able to excel in his class as a result of this opportunity to share about himself:

> I had to go up to the whole classroom and really talk about my life and everything, I remember I had an A on that project…I didn't even have to look at the board…Mr. Torres encourages that…I want to be like him, you know? (Manuel, P.Int13.5.9.12)

The same was true for Emilio who felt excited to use new software programs when Mr. Torres related the computing process to Emilio's love of skateboarding. Emilio described:

> He was asking about the things we like to do, some people say boxing, and I said skateboarding. And he told me, "Oh, so what do you need to do to do an Ollie?"…And so I told him it's all in the motion, it's all in your feet and your arms. And pressure….it feels pretty good 'cause that's what I do in life….Because in computers I thought we're going to do computer stuff, like doing Scratch or projects or trying to do a website, but I never thought he would ask me how to skateboard or something. (Emilio, P.Int14.5.7.12)

Emilio went on to explain that Mr. Torres related the act of doing an Ollie to physics which, in turn, helped students understand how to program the angles and motion of a skateboard in a software game. Emilio suggested that Mr. Torres's simple action of asking him about skateboarding helped Emilio feel more involved in the class because his personal interests were validated in relation to computer science learning. Emilio went on to say that Mr. Torres helped him feel like, "I'm gonna be somebody in life" (Emilio, P.Int14.5.7.12) by showing how academics and skateboarding could relate to one another.

A female Latina student named Allison also described that Mr. Torres's efforts to connect computer science to real life gave her hope that she could excel with technology. At one point during the school year, an animator for *The Simpson's*, who does all his artwork using computers, came to visit Mr. Torres's classroom. Allison explained that this had a positive

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impact on her because she began to realize that computer science could relate to her own love of art and drawing. She explained:

> When I would use different Microsoft things I would feel kinda dumb because I'm like, "Oh my god, I don't know a lot about computers. I know a lot about other subjects, like English or something, but not computers." [But] Mr. Torres showed me that the other subjects that you have known for a long time could actually help your life in the future…let's say sketch drawings…And knowing that, that you could actually work in animation actually brings hope up to people. Like, "Oh! I know how to draw! I could actually do something interesting and do this or do that!" (Allison, P.Int16.5.8.12)

Using computer science to validate students' personal interests and skills while building on their dreams for the future powerfully affected students' confidence in learning computer science as well as their engagement with class activities.

These examples shared by students highlight a key teacher practice of connected computer science pedagogy: to relate computer science to everyday life in ways that validate what students think, do, and hope for in their futures. The ways students experienced and articulated how this kind of pedagogy was meaningful for them suggests the importance of this particular practice.

CCSP Examples from the Classroom

One of the immediate values of employing this CCSP approach to relating computer science to real life was visible in its positive impact on student engagement. "Engagement" in these classrooms was defined by student behaviors demonstrating interest, determination, and participation in class discussions or computer science activities (e.g., student participation codes such as "wants to share perspective," "asks a question," "shows enthusiasm"). Throughout the school year, I noticed that students were most engaged in whole-class discussions and individual activities when the topic of conversation or study drew from their personal perspectives or directly impacted their lives. Consider, for example, the code co-occurrence at Presidential High

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of teacher pedagogy relating to students' everyday lives (such as relating computer science

topics to everyday life examples, building off of students' personal experiences shared during

discussion) and student engagement (such as students eagerly answering questions or sharing

personal comments, students showing enthusiasm through body language or comments about a

topic of conversation). In the diagram below, codes for pedagogy relating to everyday life and

codes for student engagement co-occurred in all field notes a total of *132 times*. In contrast,

codes for pedagogy relating to everyday life and codes for student *dis*engagement (such as off-

topic side conversations, sleeping) only occurred seventeen times:

**Presidential High: Code Co-occurence with
CCSP Practices Relating to Everyday Life**
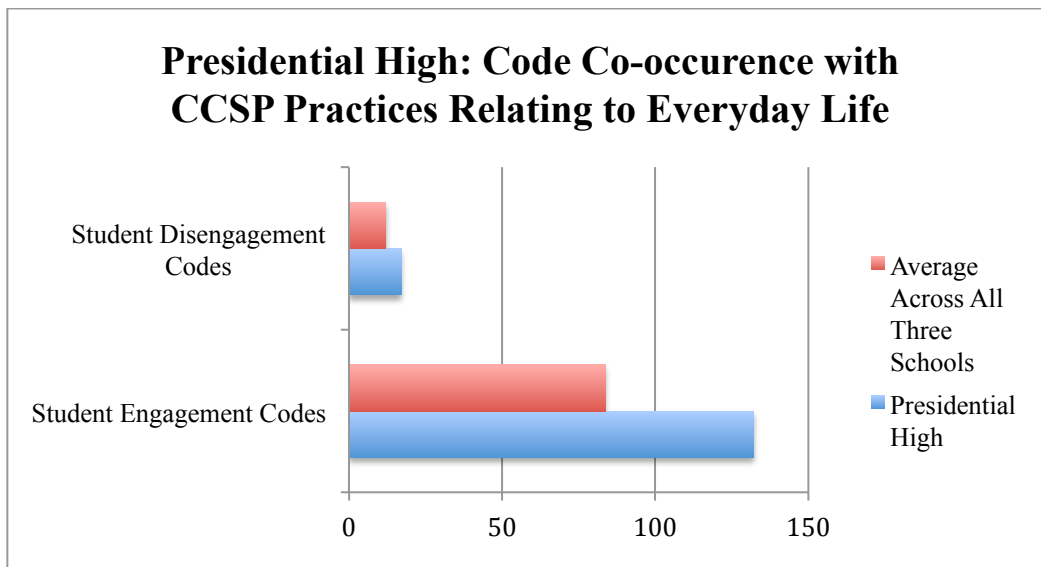
Figure 6.2: *Graph of student disengagement and engagement code co-occurrence at
Presidential High.*

Furthermore, Mr. Torres regularly validated student knowledge by asking for student input from

their personal experiences a total of *137 times* over the course of all field notes. During almost

every class meeting, Mr. Torres would ask students about their personal lives or cultural

knowledge and use this as a basis to explain a computer science concept or practice. For

example, he asked about the websites students use as an entrée into discussing website validity

(P.FN.9.9.11), he asked about their knowledge of famous tourist landmarks that were then

researched using Web 2.0 tools (P.FN.9.13.11), he asked students to provide examples of communication tools which were subsequently used to discuss human-computer interaction (P.FN.9.21.11), or he asked students about their mobile phone use as a way to discuss how their texting or calling histories could be used as data (P.FN.10.21.11).

These practices were similar at City High as well. At City High, codes for pedagogy relating to everyday life co-occurred with student engagement codes a total of seventy-one times over all field notes. In comparison, student disengagement codes only co-occurred with codes for pedagogy relating to everyday life a total of eighteen times:

City High: Code Co-occurence with CCSP Practices Relating to Everyday Life
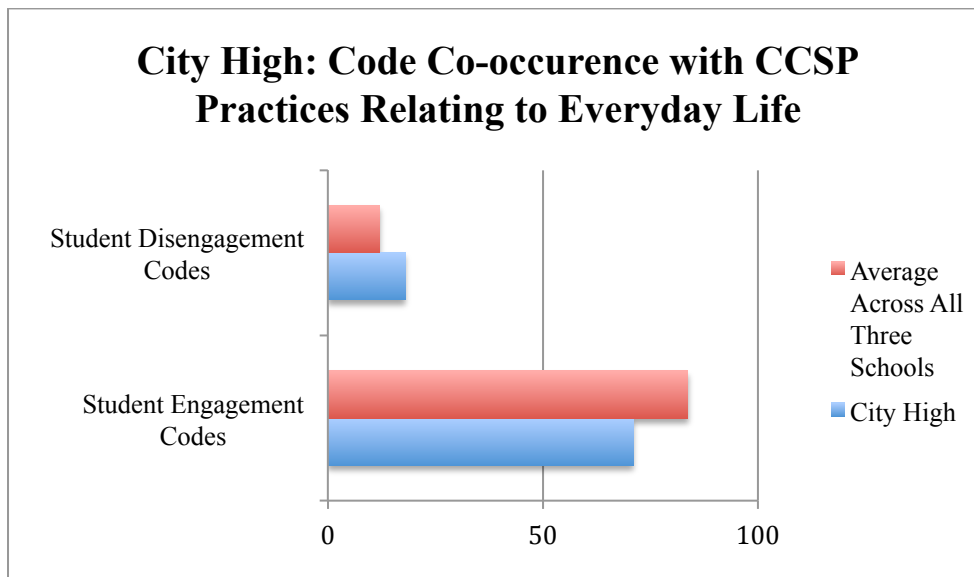
Figure 6.3: *Graph of student disengagement and engagement code co-occurrence at City High.* This pattern persisted at Midtown High where codes for pedagogy relating to everyday life overlapped with student engagement codes forty-eight times through all field notes. In comparison, pedagogy relating to everyday life and student disengagement only occurred *once*:
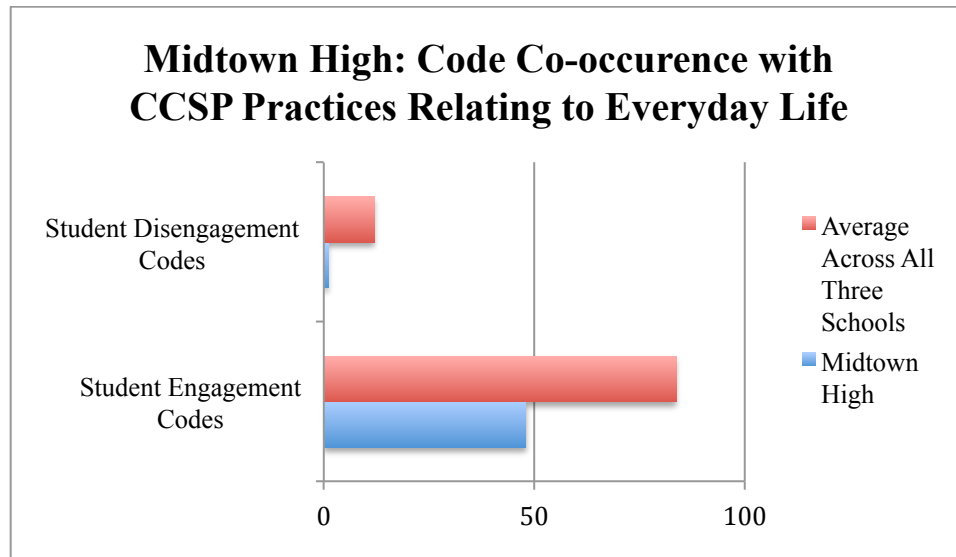
Figure 6.4: _Graph of student disengagement and engagement code co-occurrence at Midtown High._

Within each classroom, pedagogy relating to students' lived experiences, cultural practices, and everyday life may have looked slightly different depending on the teacher's personal style and tone. However, all teachers supported a similar purpose and meaning when engaging students' personal knowledge and experience across these different spaces.

A Closer Look Into A Classroom: Healthy Food, Diabetes, and Community Research

At the start of the MyData Unit, Ms. Mendoza effectively captivated student interest in collecting data about snacking habits by building directly off their knowledge of food and diet. This activity preceded showing clips of Jamie Oliver's _Food Revolution_ TV show in which Jamie Oliver asked students at a neighboring high school about the origin of different food items. For this activity, students were invited to anonymously vote on answers to the same multiple-choice questions asked in Jamie Oliver's TV show. Ms. Mendoza used a free mobile-text-to-website service. Using their personal phones, students texted their answers (A, B, or C) to a website number, and in real-time their answers would pop up on the website that Ms. Mendoza projected on the front board. Students without phones could directly enter their anonymous

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answers online as well. Throughout this activity, students watched in excitement, exclaiming "Oh! This is Interesting!" and "So cool!" as their classmates' responses appeared in aggregate on the front screen (M.FN.4.20.12). Students answered Jamie Oliver's questions including: "Where does cheese come from? A) A cow; B) Macaroni; C) The moon." Following this activity, students watched *Food Revolution* together and discussed what they noticed about the TV series in comparison to their own lives.

Without judging students about what they knew or didn't know, Ms. Mendoza followed this activity asking students how they felt if they got answers incorrect. She welcomed students' open responses about their surprise regarding the sources of chocolate or dough, then pointed out how rarely we truly know the sources of our food. Following this activity, Ms. Mendoza used the *Food Revolution* video as a tool for collective reflection on the food knowledge that the classroom community already had. This helped transition into a discussion about health issues faced by students' families and the need to research eating habits in the community. Notice in particular how Ms. Mendoza used these discussions rooted in students' knowledge and home experiences to motivate their interest in collecting data about snacking habits and thinking about community health in the excerpt below:

Before showing the video, Ms. Mendoza asked the class, **"Who knows who Jamie Oliver is?"** Nico replied that he was a chef and Ms. Mendoza added that he was a British man nicknamed the "Naked Chef." Then she joked how she originally thought that he must be "disgusting…how do you fry things in oil while you're naked?" and students laughed with her. Then she explained, "But it's not 'naked' because he's in the nude, but because he is making food that is in its raw form and is pure. So Jamie Oliver decided to make a TV show where he goes in schools to revolutionize food. We're going to see the fight that he had with [our school district]. Not 'real fists'" and Ms. Mendoza jokingly made punching and jabbing motions as if in a fight and laughed while adding, "he went to [Neighboring School] just down the street." Then she asked students, **"Why do you think he chose this area?" One student replied that this area has a "dense minority population." Ms. Mendoza nodded her head and Julio said "for the publicity." Ms. Mendoza agreed that it could be that and Dario pointed out that "obesity" was a problem in the neighborhood and Xochitl mentioned for "health" reasons.** Ms. Mendoza asked what food was like at Midtown High and students replied that it was

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disgusting while Julio pointed out that the school started "denying us salads. They're not going to serve us salads anymore!" Ms. Mendoza looked horrified and asked "What's wrong with that? Are you receiving the nutrition you need?" Students replied "no!" and Ms. Mendoza asked "And do you know what's in your food? Do you know what's in your Strawberry Frappucino from Starbucks? I'm going to show you. **Not because I'm trying to say you're stupid or anything. But it's like I said: I used to go to Carl's Junior because I knew that I loved burgers, but I didn't even think to know what was in my food**. Not my burgers, my ketchup, or anything."

She proceeded to show the *Food Revolution* episode where a girl (Sofia) tells the owner of Deno's (a local fast food restaurant) about her younger sister who was diagnosed with diabetes at 10 years old, suggesting that restaurants like Deno's are responsible for obesity and poor health in the community. After this, Ms. Mendoza paused the video and asked students to describe what had happened. Students mentioned that Sofia was talking about diabetes. Then Dario shared that his mother was diagnosed with diabetes at 8 years old. Ms. Mendoza asked, **"What is her daily life like? I don't mean to put you out…" Dario said he didn't mind and explained, "She has to go to the doctor every three days since she was eight." He mentioned how she eats regular food, doesn't eat fast food, and how she almost lost her leg. Ms. Mendoza thanked Dario for sharing, then described how her grandmother also has diabetes and injects herself every day with insulin in order to eat.** Ms Mendoza noted that she can only eat one strawberry and that's it. Dario agreed, saying that his mom can't eat any fruit because it has too much sugar. Ms. Mendoza added that if her grandmother eats too much of certain foods, she might go blind or lose a foot.

The conversation shifted as Ms. Mendoza began talking about Deno's fast food restaurant that didn't serve healthier food because of the cost of ingredients. Julio interrupted, suddenly asking, **"Wait! Is this the Deno's nearby?" and Ms. Mendoza said it was as Julio mentioned that he used to go there every day when he was in middle school.** Several students agreed that they used to go there a lot too, or still go there today. Then Xochitl said loudly, "They can avoid it!" Meaning that people can avoid eating at these places if it is negatively affecting their health. Ms. Mendoza replied, **"That's a really good point! But can they? Can we really avoid it? In our community, do we really have a choice of where to go?"** Ms. Mendoza pointed out that this was going to be something to consider while collecting snacking data in the community for the MyData Unit. (M.FN.4.20.12)

During this entire conversation and while watching the video clip, students were highly engaged: all students kept their eyes on Ms. Mendoza or the front screen without getting distracted by each other or their cell phones. Yet, what is important to consider here are Ms. Mendoza's pedagogical practices used to discuss community health and the MyData Unit research topic with her students. First of all, Ms. Mendoza rooted the initial conversation in students' reactions to their knowledge about where common food items come from. Ms. Mendoza was clear that she did not want to judge students' lack of knowledge about food, using

her own experiences eating hamburgers without considering their source as an example of how rare it is to even think about where food items originate. Next, acknowledging students' familiarity with TV culture, Ms. Mendoza asked students if they knew about Jamie Oliver. She did not assume they wouldn't know and encouraged students to share their popular culture knowledge.

Another important CCSP-oriented practice involved how Ms. Mendoza asked students to think critically about why Jamie Oliver chose a school in their neighborhood for his *Food Revolution* TV show. By asking "Why do you think he chose this area?" Ms. Mendoza pushed students to analyze the social and political motives of this famous TV chef icon. This teacher question also welcomed students to share their personal opinions. Yet another CCSP practice included how Ms. Mendoza asked students to describe their school's food. This opened space for students to critique the lack of healthy options, which Ms. Mendoza used as a way to transition into watching the video.

Ms. Mendoza further built upon student knowledge while illustrating how she valued students' personal experiences—a key CCSP practice—by asking Dario to share his mother's experience with diabetes while being respectful of his privacy. Dario was happy to describe his mother's story, which Ms. Mendoza further validated by sharing her own grandmother's struggle with the disease. This teaching method of validating students' experiences or knowledge by sharing a personal anecdote related to the students' stories is another form of CCSP that connected learning to real life. Ms. Mendoza demonstrated this practice when mentioning her lack of knowledge about Carl's Jr. hamburger ingredients as well.

Ms. Mendoza's facilitation of students' discussions about their familiarity with Deno's restaurant, which was featured in the video clip, also reflected a CCSP practice. When Xochitl

pointed out that students had the power to avoid eating at Deno's if they wanted to be healthy, Ms. Mendoza embraced this comment while also pushing her to think critically about what it means to "choose" where one eats. She encouraged students to consider whether the food options they had access to might impact the dining choices they made and how life might be different if local options were healthier. The ways Ms. Mendoza used connected computer science pedagogy to facilitate this conversation served as an important framework for beginning community data collection and analysis activities, rooting students' research projects in their lived experiences with food in the community.

Later during the same lesson, Ms. Mendoza noted, "I don't want you to do this project because I want you to change, that's on you…" but that the MyData project would be good for learning more about food in the community. Juliette shared, "I think a lot of people know some stuff and still eat it." Ms. Mendoza agreed by joking, "yeah, like gas prices. People are like 'AAAAAAAH!' and then they shrug their shoulders and still buy gas for their cars…people get jaded about the whole thing. But I want you to be aware. That's why we're doing MyData" (M.FN.4.20.12). This glimpse of Midtown High's first day of the MyData data analysis unit shows how carefully Ms. Mendoza built the computer science project upon student's knowledge, validating their experiences for deeper learning.

In this excerpt, Ms. Mendoza effectively engaged student interest in community research using computer science tools. She did this by: 1) asking students to share their perspectives; 2) validating their personal stories by relating them to her own; and 3) embracing students' knowledge of health and the community by using such knowledge as a foundation for asking important questions about local relationships with food. These pedagogical practices form an important foundation for CCSP.

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A Closer Look Into A Classroom: Framing Data Collection Based on Student Input

On another day, Ms. Mendoza continued to build on student knowledge and validate their perspectives by leading a whole-group discussion about how students would define various concepts in their data collection app questions. As a class, students discussed what they would consider to be "snacks" as well as how they would define "morning," "afternoon," "evening" for times when snacks were eaten. The conversation proceeded as described in the vignette below. Notice how Ms. Mendoza pushed students to decide upon the parameters of their data collection process while challenging their ideas with everyday snacking examples:

Ms. Mendoza projected the snack app questions on the front board and asked, "Now, as a class, when do we want to say mid-morning is? Mid-afternoon, evening, and late night?" Students called out some options that were eventually voted upon and written on the board**. Then Ms. Mendoza pushed her students to think more creatively, asking "So as a class, do we want to say that mid-morning is only 8-11 and not count things we have as a snack at 6 in the morning?"** Mike pointed out "Well, I eat a banana at around 6 in the morning…" Ms. Mendoza replied "That's your breakfast." Mike added, "Well, then I also eat more after that…" Ms. Mendoza asked the class, "Who eats snacks before you go to school?" Several students raised their hands and Juliette suggested that the mid-morning time be changed to 7-11:30 instead. Ms. Mendoza changed the time frame written on the board and then asked, "Now should we only count what we ate as a snack, not breakfast…" Mike called out, "But I eat a banana when I wake up, then I eat breakfast at school…" Julio raised his hand and said that, for example, he didn't eat much last night and didn't have a full dinner, but just ate two pieces of meat. He asked if that would be a snack or a meal. **Then Dino suggested that maybe snacks could be measured by calories where a "snack" could be something under 500 calories. Ms. Mendoza asked the class, "Do you want to limit to things under 500 calories?" and collectively students decided no.** Ms. Mendoza asked the class, "so what's a snack?" **Students called out that it should be "small" and something eaten "between meals." Ms. Mendoza wrote these ideas down on the board, then asked, "What if I go to MacDonald's and get fries…that's a…?" and students called out "Snack!"** Then she asked about yogurt with granola and students agreed that would be a snack. **A student asked if water was a snack, and Ms. Mendoza asked the class, "This is a good question, is water a snack?" the class decided no a Ms. Mendoza added, "Should we consider liquids?" and students had mixed responses**. Then students decided that some liquids should be considered a snack and Ms. Mendoza wrote "some liquids" on the board and asked for students to provide examples of which liquids counted. Students said smoothies, Boba, Jamba Juice, Pink Berry, Frappucinos. After this discussion, Ms. Mendoza instructed, "Can you put these as notes in your phones?" (M.FN.4.25.12)

In this excerpt from the first days of data collection, one can see that Ms. Mendoza let students guide the direction of their projects rather than forcing her own beliefs about how they should collect data. This is another example of CCSP teacher practice. For example, when students asked questions such as "Is water a snack?" or "Should we define snacks by calorie count?" Ms. Mendoza redirected the questions back to the students to collectively decide. In this way, their perspectives and personal snacking practices were embraced, further defining the project according to students' personal experiences and beliefs.

Ms. Mendoza also encouraged deeper thinking about these data collection definitions by offering snacking scenarios or asking probing questions. Consider, for example, how Ms. Mendoza asked if "mid-morning" would exclude snacks eaten at 6am. Or consider how she asked students how they would define fries in their data collection surveys. In this way Ms. Mendoza supported students in defining their own definitions of terms and snacks for their data collection process while also encouraging them to reflect on how they might respond to different situations according to these definitions.

By basing the parameters of data collection according to students' personal definitions of time, snacks, etc., Ms. Mendoza demonstrated how she valued students' perspectives. She encouraged students to root this computer science research project in their everyday lives. This teacher practice of welcoming student perspectives and basing the learning process in such perspectives is key to CCSP.

A Closer Look Into A Classroom: Relating to Popular Culture

Mr. Torres at Presidential High also encouraged students to think about computer science in relation to their personal lives in ways that contribute to our understanding of CCSP practices.

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During an activity in which students learned critical media literacy skills by analyzing the

validity of various websites, Mr. Torres related website testing to a student's favorite TV show:

> Mr. Torres asked students what websites they like to use. Harrieta called out: "Hulu!"
> Mr. Torres asked what students watch on Hulu and Harrieta offered, *Rookie Blue.* Mr. Torres
> nodded his head, describing that this was a case-solving, police show and then, as an example, **he
> described a scenario in which students had to solve a problem on the TV show. Harrieta
> mentioned that maybe it could be a murder scenario. Mr. Torres accepted her suggestion
> and asked, "Okay, so how do you solve the murder?"** Harrieta responded "Fingerprints!" and
> others called out, "Evidence!" Mr. Torres probed, "What kind of evidence?" Students replied
> hair, blood, etc. Then Mr. Torres said, "Ok, so we're doing all this research to find out who is the
> murderer. Do you think it's important to have valid evidence?" Students responded in unison:
> "Yes!" as Mr. Torres asked, **"So it's important that the evidence matches the right person?"**
> Again, students responded in unison: "Yes!" as Mr. Torres went on to say: "Otherwise you could
> send someone to jail who's innocent!" (P.FN.9.9.11)

In the vignette above, Mr. Torres used students' interests in Hulu and the TV Show *Rookie Blue*

to highlight the importance of checking carefully for website validity. He began by embracing

students' popular culture knowledge as a source for imagining a problem-solving scenario. Mr.

Torres then asked students to share how they might solve a murder case using their recently

acquired problem-solving skills learned earlier in the unit. As students shared ideas about where

they might find evidence regarding a murder case, Mr. Torres related this process to research

regarding website validity. Drawing parallels to the ways that detectives make sure their murder

evidence matches the right perpetrator, Mr. Torres emphasized the importance of making sure

information on a website is trustworthy. Simple but meaningful CCSP acts like this happened on

a regular basis in Mr. Torres's classroom. For example, Mr. Torres regularly referenced movies

to consider computer science and robotics (P.FN.9.27.11), when introducing the problem solving

unit, he asked students to describe a problem (a student said "going to school") and then used

this as an example for brainstorming ways to solve that problem as a class (students shared going

to sleep earlier, accepting the reality, or eating better; P.FN.10.18.11), and he explained

"algorithms" in terms of how computers know how to do a *Google* search (P.FN.11.2.11). In this

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way, Mr. Torres showed students that their personal interests, knowledge, and experiences could relate to computing activities.

A Closer Look Into A Classroom: Valuing Student Knowledge

At City High, Mr. Santos also regularly made connections between computer science and everyday life while sharing *Youtube* videos about how "Shift Happens" in our ever-changing world due to technological advancement (C.FN.9.15.11) or about how people have used information from the internet to make major discoveries or innovations (e.g., a sixteen-year-old girl who discovered a supernova or a surfer seeking the perfect wave, C.FN.9.29.11). Yet beyond sharing ideas related to real life, Mr. Santos also supported the development of students' computational thinking skills by drawing on their personal knowledge. Mr. Santos's methods of embracing students' ways of thinking or problem solving reflect an important CCSP practice. In the vignette below, students were asked to calculate the total number of handshakes that would happen in a room of ten people where people can only shakes hands with each other once. Notice the ways that Mr. Santos valued student knowledge through the problem solving process:

Malia raised her hand and asked for Mr. Santos to check her answer to the handshake problem. As Mr. Santos walked over to her desk, she showed her calculations on her cell phone calculator that displayed: "9+8+7+6+5+4+3+2+1." Malia explained, "If you have ten people in the classroom and they don't shake their own hands, then you can't include yourself and the person you shake hands with, so it would be 9 handshakes plus 8 plus 7…" She held up her calculator with the addition on it and pressed enter as her activity partner (Larry) and Mr. Santos watched. The total added up to 45 handshakes. Mr. Santos asked how it would be with twenty people in the room and Malia said it would be the same approach except 19+18+17+16, etc. Mr. Santos asked Malia why she would begin with "19" in that addition equation and she replied, "Because there are twenty people but you have to take yourself out." **Mr. Santos noticed that her partner (Larry) was looking confused and said, "I'm not sure if Larry understands. If he can't explain it then he doesn't understand it." Larry was silent a moment, then agreed that he couldn't explain the problem. So Mr. Santos turned to Malia and asked her to explain it again.** Malia repeated, "So, if there are ten people in the classroom, so you exclude yourself so then you shake 9 hands. But 9 people has to also exclude who they just shook hands with, so you're 9+8+7+6+5+4+3+2+1 and then I get 45." Mr. Santos asked Larry if he understood and Larry nodded his head. **To prove he understood, Mr. Santos asked him to explain it in his own words** and Larry said: "Ten people. Doesn't include me. Nine shakes.

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Next person shakes eight hands because doesn't include self. Then next person shakes seven hands because doesn't include self…etc." Mr. Santos smiled and said this was great. Then he asked Larry to put this down in writing in his journal so that their group would be ready to explain the problem to the class. (C.FN.10.17.11)

In this vignette, Mr. Santos showed his trust in Malia's skills and knowledge by respectfully listening to her idea and then testing this approach by asking her to apply it to a new situation (from ten people to twenty people in a room). When her partner looked confused, instead of simply restating what Malia shared, Mr. Santos encouraged Malia to explain her idea to Larry again so that he could learn directly from her. This CCSP approach validated student knowledge and encouraged peer-supported learning—two key connected learning contexts. Furthermore, Mr. Santos did not discourage Malia from using her personal phone in the classroom for this activity, even though mobile phones were not supposed to be used during class. Instead, recognizing that Malia was using the tools she had on-hand toward solving the problem, Mr. Santos embraced Malia's approach without scolding her use of electronics in the classroom.

Throughout the rest of this particular class period, other students approached the same problem in a variety of ways—drawing pictures, using the alphabet to signify individuals in the room and matching them up for handshakes, building charts that counted the total number of handshakes, etc. Mr. Santos embraced all these approaches, caring more about the thinking and process behind solving the problem than the answer itself. Mr. Santos also encouraged various students to teach each other their different methods for counting handshakes. Mr. Santos's pedagogical approach showed that he valued students' varying ways of seeing the world in his computer science class while also building students' confidence in themselves. These teacher practices of asking students to share their approaches and then acknowledging these approaches

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by asking students to also teach their peers reflect what CCSP building upon student knowledge can look like in the classroom.

These snapshots of the three dissertation classrooms reveal how CCSP involves pedagogy that both builds on student knowledge—from personal experiences, cultural practices, language, interests, etc.—to learn new computer science concepts, but also to gain new computational thinking skills. The teachers not only welcomed students to share their ideas and perspectives, but also were quick to embrace these ideas and perspectives as tools to access computer science ideas related to data, website validity, problem solving processes, etc. In this way, the various worlds and identities from which students came from (at home, among friends, from church, etc.) were validated within the academic space, recognized as resources and not handicaps.

CCSP Highlighting Computer Science as an Academic Tool to Address Real Social Issues

Interviews with students overwhelming highlighted that they cared about equity issues in the real world. Furthermore, students wanted their in-school learning to reflect their personal interests around social issues in their out-of-school lives. As Alejandra explained, "I like to look for things that are happening in our world…What is wrong with our world, what is actually happening outside" (Alejandra, C.Int10.5.23.12). As a result, students appreciated when their teachers made connections between computer science and social issues in their local communities. James explained:

> He told us about all these things that you can do with the computer and how you can benefit not only your life, but life around you…He's giving us freedom to actually really get involved with the subject, see at it from any point of view we want…and who doesn't want freedom? I mean we've been fighting wars for it! (James, C.Int3a.5.14.12)

Or as Lisa explained, she really appreciated the MyData data analysis unit and her animation projects "where you had to do something about the community and doing research [because] that

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helps you outside the classroom and that helps you draw knowledge in that you have already"

(Lisa, C.Int4.5.17.12). Similarly, Darrell noted:

> It's surprising because you wouldn't expect [to talk about social issues in a CS class], but it's a good surprise!…It's important because when we leave high school, we're not going to be going into a world where it's just tests…if you're a hard-core math or science person in the laboratory, you're still going to have to deal with issues…there's still discrimination in the world, there's still racism, sexism. So, it's important to be able to apply it to everything…in a computer science class, you could be doing presentations or you could be looking at data from other cultural groups. (Darrell, C.Int2.5.30.12)

Relating social issues to computer science was important for students to "Know more about

everything and make us a better person" (Hyun, C.Int14a.5.7.12) as well as "to help us and

remind us that we're all not so different and there's other people that need help. There's actually

something that we could do about it" (Guillermo, M.Int9.6.1.12). In general students across all

schools agreed that discussing real problems in the community and world at large in—pollution,

racism, high unemployment rates, gang violence, etc.—in computer science class was important.

Students also recognized that the ways their teachers framed computer science in relation

to social issues made the field seem more accessible to them. For example, Manuel remembered

how Mr. Torres talked about the race- and gender-based history of skateboarding before students

used a skateboarding software program. Through photographs, Mr. Torres showed how 1950's

skateboarders were White males, but that today's skateboarders also included African American

men like Terry Kennedy and even a local Latina who became a famous X-Games skateboarder.

Manuel noted that Mr. Torres used this discussion about race and gender in skateboarding as a

way to talk about diversity in computer science:

> He showed us the little picture of the little kid trying to make a skateboard, it was a White person, right? And now anybody could do it…he said to us to be clear that women and guys have the same rights now. The woman has the same possibility of being a computer scientist too. (Manuel, P.Int13.5.9.12)

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It was in this interview that Manuel mentioned that he would like to be a computer science teacher just like Mr. Torres.

In Ms. Mendoza's classroom, several young women also mentioned how computer science felt more accessible because of the ways the teacher framed this academic field in relation to social justice issues. Juliette noted how the teacher transformed her perspective of computer science from something scary to something she could actually enjoy: "I really like the whole theme of social justice…I think it's definitely made me open my eyes…it was like taking that red pill from Morpheus, you know, from *The Matrix*, because I completely, I was able to see things that I never really knew!" (Juliette, M.Int3.6.8.12). Juliette began the school year feeling uncomfortable with computer science, but described gaining confidence because her teacher related computer science to real social issues that Juliette had more familiarity with. Anthony also changed his perspectives about who can pursue computer science because of Ms. Mendoza's pedagogical approach:

> Say you see Bill Gates—he's White, he's a guy—and that's what people gonna thought, "oh that's totally computer geeks"…But the answer is that everybody could be computer scientists, so that somehow motivates some students who might be Latino…Do you know like *Ratatouille* [a Disney animation film]? "Everyone can cook!" And it's just like [that]: Everyone can be computer scientist too! (Anthony, M.Int5.6.1.12)

Xochitl, Julio, and Lena all mentioned an activity where Ms. Mendoza asked students to draw pictures of what they think a computer scientist looks like. Ms. Mendoza had students draw these pictures before going on a field trip to meet the Spelman College Robotics Team—an all African American, female robotics team. Xochitl's perspective completely changed after this experience: "People think that only White men or Asian men do computer science…[but] she took us to the field trip to see how it's not only men doing things….It doesn't matter if you're woman or a man

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or what age…from right now you could start learning how to do computer science" (Xochitl, M.Int6.5.10.12). Lena (who drew a 30-40 year old, Asian male with glasses) added:

> A lot of times we stereotype…it's part of our fault and society's fault because society puts us to think a certain way. So that's how I thought a computer scientist looks like. But when we went to [the field trip] that completely changed. It was actually women, they were colored, and they were young!...that changed my way of thinking. (Lena, M.Int2.5.10.12)

Similarly, Julio stated:

> I'm not gonna lie, we were surprised, because it was actually female African American ladies who are just doing it big in the computer science programs…things like that have definitely changed our point of views in life…Now we know that anything is possible, anyone is capable of doing it….you never know, some Hispanic kids, African American kids, Asian, or whoever it is, can be the next top computer scientist. (Julio, M.Int1.5.4.12)

These teacher-led discussions about race in computing reflecting a key CCSP practice impacted students' self-perceptions as potential computer scientists. As Lena pointed out:

> At first when I came in, I thought it was your typical computer class…typing, Microsoft, Powerpoint…But when she brought up everything, like when we did the html, I was like, "WOW, this is *so Myspace*!" Like, *Myspace* was in the day, but I remember that you didn't write the code, you just copied and pasted the code, but doing it yourself showed me how it's a lot of work [but] after I finished a project, I was like "Wow, you know, this is really nice and I did it *myself!*" So it's something that I can call *mine*. I think that's really cool…Because it made me think that if I wanted, it could be a career for me as well. And not only just a class. (Lena, M.Int2.5.10.12)

During this specific lesson when both Lena and Samson mentioned how html reminded them of *Myspace*, Ms. Mendoza welcomed their personal knowledge and interests in social networking sites (M.FN.1.13.12). This, hand-in-hand with Ms. Mendoza's discussions about equity in computer science, helped Lena feel more confident about pursuing the field. These CCSP teacher practices made computer science feel like an accessible academic pursuit as Nico explained, "most of [my classmates] are like, 'Hey! I want a career in computer science!' because of this class" (Nico, M.Int8a.5.11.12).

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A Closer Look Into A Classroom: Relating Research to the Local Community

The ways that teachers related computer science to real life social issues while encouraging students to actively challenge social inequities was visible on multiple occasions at all three schools. For example, before beginning the MyData data analysis unit, Mr. Torres at Presidential High talked to his students about access to healthy foods and economic opportunity in their community. Students were highly engaged in this discussion, reflecting on ways that their research in the computer science class could positively impact their neighborhood. This is described in the following vignette:

Mr. Torres noted, "Yesterday, as I was returning to Presidential High from a game with my student-athletes, we passed by the corner of ---- and ---th Street. What's fenced off over there?" Some students mentioned that there was a "big old lot" while one student remembered: "---- Farms." Mr. Torres nodded his head saying, **"Whenever I pass that, I get a pit in my stomach because there used to be a farm on that lot—where your family, neighbors, and people in your community used to grow fresh food. Would you say that the lack of fresh foods in your community is a problem? How many of you go to fast food places like Jack in the Box or Burger King 1-2 times a week?"** Elijah raised his hand but others hesitated. Mr. Torres raised his own hand and said, "Don't be shy! We're not judging! And would you say that this occurrence in the community changes the way we eat?" David added, "Plus, it's abandoned," noting that the empty lot was wasted space in the community. Mr. Torres agreed with David and said, "Let me tell you a story. So originally there was a developer who bought the land to make a strip mall or something—but the people who farmed there took him to court because they pointed out that they had been farming there a long time and that was the only farm in the area." Then Mr. Torres complicated the issue, asking students if they ever went to wealthier communities that had big shopping centers instead of abandoned lots, adding, "Do you ever go to [name of community] to go shopping where there's a Home Depot and other big shops? Do you notice any of those shops here? Places where you could shop or get a job?" Students agreed that there were not quite as many options in their neighborhood.

Mr. Torres continued: "Could we say that's a problem in our community? The places you could shop and get a job. Or places to find farm-fresh food? I'm not saying that one way is right or wrong…this is just something to think about." Students attentively nodded their heads as Mr. Torres continued, **"So you could develop a cause…or wait a minute…what's the right word…?"** and then Emilio called out, **"A campaign!"** and Mr. Torres smiled, continuing: "So when I graduate from high school and go to college and need a part-time job—we might need to travel outside our community to get a job. So we might collect data to say that we need jobs here. But maybe Julieta wants the farm back and so she collects data on the nutritional health of fruits and veggies and about the obesity problem in our state and finds out that from 2007-2012, child obesity annually increases. **And maybe Julieta's research shows us that if we eat healthier,**

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then obesity will go down. So here are two examples of campaigns you will be championing!" Students smiled while nodding their heads in agreement. (P.FN.2.8.12)

In the excerpt above, Mr. Torres effectively motivated students' interest in collecting and analyzing data using computer science tools by relating academic learning to real concerns in the local community. His teacher actions contribute to our understanding of a CCSP approach by building off students' local knowledge of an empty lot to reflect on the lack of farm-fresh food and job opportunities. While highlighting two major social issues—food deserts and unemployment—Mr. Torres pointed to the ways students could use data in computer science to change these community problems. Consider how Mr. Torres created a learning context (by asking students about neighborhood geography and history, their relationship to fast food, access to jobs, etc.) in which students could reflect on their personal agency to use academic learning in a way that would change these life situations. He began by discussing the empty lot that students often pass by in the neighborhood. Then he described how there used to be a community farm at this lot that gave people better options than the fast food restaurants in the neighborhood. Mr. Torres built off this idea to relate to students' needs for jobs and the lack of jobs in the community. Then Mr. Torres welcomed students' suggestions for how to address this problem, framing the MyData community research topic around a real neighborhood problem. The ways Mr. Torres asked questions about local issues and tied them to student knowledge are central to CCSP.

A Closer Look Into A Classroom: Data Collection and Demographics

To emphasize the importance of thinking about social issues in the community when collecting and analyzing data, Ms. Mendoza asked students to reflect on how their snacking data might look different if collected by people from different demographics. The resulting discussions pushed students to engage in critical thinking around race, age, socioeconomic class,

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and gender in ways that related data to everday life and students' stereotypes about people different from themselves. Ms. Mendoza effectively highlighted issues of equity and the power students have to impact social problems through computer science as described below:

Ms. Mendoza projected a plot of healthysnack vs. timeplot on a line graph saying, "So this shows your healthy levels. **How would they change if this was done by only men?**" Clara noted that the snacks would be unhealthy and Ms. Mendoza clarified, "So mostly below three?" and Clara said yes. When Ms. Mendoza asked Clara why she thought this, **Clara replied, "Because men don't care what they eat." Dario quickly called out, "That's sexist!" and Ms. Mendoza said that he made a really good point and asked him why he thought it was sexist.** Dario explained, "Because not only men eat that way. Women eat unhealthy too!" Ms. Mendoza laughed and jokingly said, "Whoa! Whoa!" while holding a yard stick between Dario and Clara as if to prevent them from having a fist-fight. Dario laughed and then Clara said gently "I didn't say *all* guys…" as Dario quipped back, "Yes you did!" Ms. Mendoza and the class laughed in recognition of Clara's mistake as Ms. Mendoza asked, "What about if they were only women?" Clara said that the healthy levels would be 3-5 and Dario said that there would be more cravings at night. Ms. Mendoza laughed and said, "Okay, if they're pregnant maybe! What if the women were pregnant?" Sung Woo pointed out that pregnant women eat more and Ms. Mendoza burst out laughing and told them to pass that idea by Ms. --- [a teacher at the school] who was currently pregnant.

Ms. Mendoza then asked students, **"What if college students were doing these surveys?"** Xochitl replied, "It [health levels] would be all over the place because some care, some don't." Jack pointed out, "It depends if there's a healthy store nearby" (suggesting that access to a health food store might might affect data results). Ms. Mendoza added, "Or if they have a meal plan." Then **Ms. Mendoza described all the different supermarkets surrounding a large, local, state university near their school. She described that there was a Ralph's, Gelson's, Trader Joe's, and Wholefoods. Then she asked "How would it be there?"** Dario said, "Up and down" and Nico said, "When people are under stress, they may not have time to cook, so they'll probably eat unhealthy." Ms. Mendoza said this was a good point and asked, "So would they eat more snacks? Or would it depend on time? Like around finals and exams time, you're all like 'aaraaraar'" and Ms. Mendoza made joking face-stuffing noises as she gobbled imaginary food. Students laughed as she joked about the fact that the Domino's pizza deliveryman knew her first name, last name, and phone number during exam time.

Then **Nico pointed out, "Doesn't it matter if we're in the city or not? In the city, there's more fast food around, but if you're in a rural area, maybe you don't have as many…"** Ms. Mendoza replied, "Okay! Good point! What if the university was in the middle of a rural area?" Nico thought it would be more healthy, and Ms. Mendoza retorted, "Right, but in urban areas, we have more options instead of just one supermarket" and she described that a lot of small town markets have very few options due to their isolation.

Then, reflecting on snack cost, Ms. Mendoza asked **"How would this change if the surveys were done by African Americans? Would it change?"** Students were silent and Ms. Mendoza laughed saying that it was okay for them to share their opinions on this and not hold back. She recognized that it was difficult to talk about race in the classroom, but that this was a safe space where people should not judge and should just openly consider. Then Dario replied,

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"It would be cheaper." Ms. Mendoza asked why and people were quiet again. **Then Dario finally said, "Because colored people are lower class." Ms. Mendoza gently corrected him, "Let's say 'living in poverty'" Then Dario clarified: "And when I say 'colored,' I mean Latino people too."** The majority Latino classroom continued to be quiet after this comment and Ms. Mendoza said, "Hey! We're all adults here! We can say it! Why are we so uncomfortable?" Then she joked about her eighth graders who felt uncomfortable saying that the president was "Black" even though it's true. Students laughed with her.

Then **Ms. Mendoza asked, "What if only White students did these surveys?"** Clara said that the snacks would be healthy and Ms. Mendoza pointed out that health level was not part of this particular graph. Then Clara corrected herself and said, "The snacks would be more expensive." **Nico countered this, saying, "It depends on which state."** Ms. Mendoza nodded her head and replied, "So let's say we're in our home city [a diverse, big city]" to which Dario responded, "There are wealthy people in my apartment just next-door." Dario explained that not only White people were wealthy, but then Jack disagreed, saying that White people eat more expensive snacks because they have "more income." **Ms. Mendoza asked, "What if they're white high school students living in rural Tennessee?"** Jack changed his analysis, saying, "I think it would be less than $1" (Referring to the snack prices being cheaper). Ms. Mendoza replied, "So you're saying that socioeconomics matter?" Jack said, "Yes, it does matter." Ms. Mendoza nodded her head in agreement. (M.FN.5.15.12)

The vignette above shows the careful ways that Ms. Mendoza pushed students to think critically about data by relating data to real race-, socioeconomic class-, and gender-based social issues. Drawing from interpretations of various types of graphs, Ms. Mendoza encouraged students to consider how the data might look different or similar if collected by men only, women only, college students, African Americans, or White high school students living in rural Tennessee. Through this process, students' stereotypes about the eating habits of men and women surfaced, which their peers openly challenged. This created space to think more critically about what people assume regarding people of color and White people, as Nico questioned urban vs. rural contexts, Dario noted that people of color could be wealthy too, and Jack recognized that urban White and rural White people may not have the same sort of income as each other.

Ms. Mendoza's teaching practices informing how teachers might engage CCSP in the classroom included the following. First of all, Ms. Mendoza honestly recognized how challenging it was to talk about race and socioeconomic class in school. She emphasized how the

classroom was a safe space where students should not judge what is said, especially in relation to topics that are difficult to talk about. She also released tension around discussing race by joking about her middle school students' inabilities to say that President Obama is African American.

Secondly, once students opened up, Ms. Mendoza taught students terminology for talking about these issues in less offensive ways, empowering them with new tools for speaking about challenging social issues. For example, when Dario described African Americans as "lower class," Ms. Mendoza suggested saying "living in poverty" instead because his comment could be interpreted as a comment on cultural practice rather than economic status. It's possible that this conversation should have been pushed to a deeper level. Ms. Mendoza could have questioned why Dario believed African Americans make less money or why all African Americans were being lumped into one economic group. Ms. Mendoza could also have begun to question what might be problematic about terms such as "lower class" or "living in poverty" and why she corrected Dario's language. While Ms. Mendoza showed an important effort to openly discuss these topics, this is one challenge to a CCSP approach. Teachers must be open and willing to talk about these complicated topics.

Thirdly, Ms. Mendoza gently helped students question their stereotypes and assumptions without judging their ideas by carefully ordering her questions in a specific way. For example, by asking how White people's snacking data might compare to the students of color in the classroom, but then following this with another question asking how White people in rural Tennessee might compare, Ms. Mendoza was teaching her students to think in more nuanced ways about what they assumed regarding White people or people of color without directly pointing fingers to say any one interpretation was "wrong."

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Fourthly, Ms. Mendoza rooted this entire conversation in local knowledge (e.g., students' familiarity with the local state university) and students' shared ideas (e.g., when Nico mentioned snacking might be state-dependent, Ms. Mendoza clarified the location within her question).

This series of questions, answers, and speculations rooted in various graphs of student data represent an effective way that Ms. Mendoza engaged students in thinking about data analysis in relation to real life social issues regarding gender, age, race, wealth, and access to healthy food. By seeing how their interpretations of the same kinds of data might shift depending on the demographics of the data collectors, Ms. Mendoza began to show students how data analysis is not a purely objective process. Student interpretations or assumptions impacted how they thought data might look. In this way, Ms. Mendoza helped students consider the power they have as data analyzers and researchers.

A Closer Look Into A Classroom: Using the Internet to Positively Impact the World

Presidential High teacher Mr. Torres also did not shy away from discussing social issues impacting the local community and world, often connecting computer science to students' abilities to affect positive social change. In the following vignette, Mr. Torres followed a discussion about the ways people use the internet with a conversation about how people have used this computing tool to improve life for others:

Mr. Torres asked, "Are there other ways you use the internet?" After a pause, Harrieta said with a laugh, "Mistreat it." Mr. Torres smiled and asked her to elaborate and she said that people searching for pornography are "mistreating" the internet. Mr. Torres nodded his head and asked for more examples. Manuel called out, "Viruses" as other students chimed in that people get involved in hacking and sending spam. **Mr. Torres wrote these examples on the board, but then asked students to think of "how we can use the internet to improve the community?"** Harrieta responded, "Nonprofits!" Mr. Torres responded enthusiastically, "Tell me more!" Harrieta mentioned that nonprofits "help people out." Mr. Torres agreed and asked, "How else?" And Harrieta added, "Donate!" Mr. Torres replied, "Oh, okay. A website for donations." After adding this to the board, Mr. Torres asked the class if they knew who Jerry Lewis was. Several students called out, "Yeah!" and Mr. Torres asked them who he was. Nobody responded. Mr. Torres laughed and proceeded to explain that Jerry Lewis was an

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actor/comedian who would go on TV—before the internet existed—and raise money for children with muscular dystrophy. He said that Jerry Lewis was able to help a lot of children with this difficult disease and all through a TV channel. Then Mr. Torres asked: "But now, instead of hosting a fundraiser on TV, can people host an internet channel and raise funds?" David responded, "Yeah!"

Mr. Torres went on to describe the winner of CNN's "heroes awards" who got up early every morning to feed day laborers in the Bronx. He also described another man who created "Wine to Water." Mr. Torres noted, "He was a bartender and wanted to use his skills toward something meaningful. This man knew how all over the world, people in Third World countries—like Africa, etc.—had no clean drinking water. So using the skills he had, he started raising money by hosting parties where affluent people could donate money to help young children in these countries that had no clean water. Imagine having to go to a puddle filled with bugs, mud, and other stuff and needing to drink your water out of that?!" Mr. Torres proceeded to describe how this man doesn't just raise money, but actually travels around to other countries and teaches people how to build filters that can provide clean water for families of 10-15 people so that they can have clean water and bathe, drink, etc. He emphasized that this man "Teaches them how to create their own filters—now they're self-sustaining." **Mr. Torres then said pointedly: "I want you to remember that it's more than just a box in front of you—more than just *Facebook* and *Myspace***…Every time you are faced with something tough, remember that there are kids without clean water and kids your age who don't know what the internet is because providers like Timewarner don't go to their cities or countries in Africa and install the internet. **You future computer scientists and doctors and lawyers: it's your turn to help other people with the knowledge and skills you have** just like the people I described today." (P.FN.9.7.11)

Mr. Torres used examples from real life to emphasize that students could employ technology and computer science toward positively impacting the world. Building off of the examples students shared of both negative and positive uses of the internet, Mr. Torres described how both famous and everyday people employed technology and their personal knowledge/skills to help others. This discussion caught the attention of Mr. Torres's students, reflecting their interest in these issues. Mr. Torres grounded human-computer interaction topics in real social activism combatting disease, poverty, lack of jobs for immigrants, and clean water issues. This created a strong foundation for students to consider how their own research in the MyData data analysis unit could have a larger impact than just a course grade. Mr. Torres's pedagogical actions were intentional—from the ways he drew off student knowledge to share real social activism examples from "regular" people to how he shared his personal experiences. While he

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incorrectly suggested that Africa was a single country, Mr. Torres's efforts to connect academic learning to real social issues were strong. These actions illuminate what CCSP relating to social issues can look like in the classroom.

A Closer Look Into A Classroom: Computer Science and Gentrification

Earlier in the year, Mr. Torres discussed why students should care about computer science for their futures. He couched this discussion within the historical context of their urban community of color. In the vignette below, notice how Mr. Torres highlighted equity issues in computer science and students' power to change such trends:

Mr. Torres began class saying, "So this is my little pep talk for the day. I don't want a mediocre life for you. One of the founders of this program is a woman named Jane Margolis who I highly respect. She's a Harvard Grad—and she could have taken any job under the sun because she has an IV League degree, but she chose to make a difference in our city and at schools like Presidential High because she saw the way education was and that it was not equitable and not fair and not equal across the board. So that is why she helped to create this class for you so that by the time you leave this class, you'll know how to build a website, how to create games, how to create animations, how to build a robot and program it." Then Mr. Torres asked, "Did you notice the Fresh 'n Easy that opened up on ---- Street?" Several students nodded their heads. Mr. Torres asked: "What do you notice about the kind of people who go there?" Belén called out, "They're White people." Mr. Torres agreed this was true and explained, "Back in the 1950's, a thing called 'White Flight' happened…" Mr. Torres continued to describe how the area surrounding their school used to be highly populated by White people because there were lots of jobs in the center of the city. However, as immigrants started moving to this city, White people began to move out to the suburbs where they could have yards, big houses, and cleaner air**. Mr. Torres noted, "But now the cycle is turning back where Fresh 'N Easy is popping up and White people are coming back into the center of the city. Large companies are buying up your land, jacking up the prices of real estate, and pushing you out of the city. This is called re-gentrification. So if you like living here you should think about this. And, so, if you're going to be competing against those people, when that happens, it's not the color of your skin that matters, but what skills you have."** (P.FN.9.9.11)

While Mr. Torres's words may have appeared preachy, his intention was positive. He wanted his students to understand why it was important to learn computer science within the historical context and current events of their community that was undergoing gentrification. For Presidential High students coming from families with little economic wealth, finding jobs in the

local community that could assist their parents and siblings was of high concern. Providing students with the socioeconomic and racial history of their community—that was unknown to most students—provided some context for understanding the changing times of urban renewal and how that could either positively or negatively impact their futures. In this vignette, Mr. Torres began by talking about why students should be excited to take Discovering Computer Science. He emphasized how access to computer science was important for students' home communities and that equity issues in education were directly impacting students' lives. He used this as a springboard for also examining the changes occurring in the local community—the opening of a new supermarket that was patronized mainly by wealthier White people—and related this to the reasons why students needed to prepare themselves with a good education to be able to maintain their communities despite gentrification. Mr. Torres motivated his students to consider not only how computer science related to real life issues regarding race or socioeconomic class, but also how students could empower themselves to succeed within the changing urban landscape.

Of course, gentrification is not an easy topic to discuss in a computer science class. In fact, Mr. Torres could have explained more about the reasons behind "White Flight," the impact of building highways and suburbs, or the complex capitalist relationships influencing changes in Metro City. Yet, Mr. Torres's efforts to guide students in thinking beyond their daily classroom lives to consider how school learning relates to larger social issues was incredibly important for engaging student interest in computer science. Showing students how their Discovering Computer Science experiences related to larger social issues gave students an opportunity to see why computer science learning mattered. Couching computer science within real social issues—as demonstrated by Mr. Torres—is an important tool in CCSP.

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Mr. Torres's and Ms. Mendoza's pedagogical efforts that directly related computer science and data analysis skills to both current societal problems and students' roles in positively impacting these problems proved both motivating and engaging for their students.

CCSP: Facilitating Peer-Supported Engagement and Collaborative Computer Science

While relating to students' interests, validating student knowledge, connecting academic learning to real social issues, and encouraging students to use computer science as a tool for positive change, all three teachers also facilitated collaboration instead of competition in their classrooms. The ways teachers encouraged students to work together on various projects reflected a key aspect of CCSP practice. This was especially important since survey results showed that 56% of students at all three schools reported learning best in groups, while only 7.5% of all students preferred learning alone.

Teachers used both formal and informal pedagogical tools to create peer-supported learning contexts. Formal CCSP practices included assigning specific group roles to students, physically arranging students in collaborative groups, and explicitly asking students to reflect on collaborative work processes. For example, in Ms. Mendoza's class during the first collaborative project students created, Ms. Mendoza brought out a box filled with collections of cards describing group-work role titles, rules, and suggested things to say/ask in those roles. Roles included "facilitator," "task manager," "reporter/recorder," "time keeper," etc. (M.FN.9.27.11). Similarly, in Mr. Santos's class, students always sat at computers arranged in groups of four facing inward. Each group of tables had a station number that students quickly realized defined their group numbers. At the start of every early project, Mr. Santos would assign a group "captain" to take charge of assigning responsibilities for the project and to ensure the project was

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completed (C.FN.9.11.11). In Mr. Torres's classroom, during the first group project, students were given roles such as "project manager," "recorder," and "fact checker" (P.FN.8.19.11).

On another occasion, Ms. Mendoza started class by asking students to respond to the journal questions: "How will we ensure equality in our group? How have we progressed as a team in completing our project? What obstacles have we faced?" (M.FN.9.27.11). Not only did students write journal responses, but Ms. Mendoza also asked students to discus what they had written with their small groups, then she led a whole-class discussion about how to define collaborative group equality and norms. These explicit emphases positive collaboration practices created an important tone for the class, emphasizing a responsibility to one another and valuing peer-support.

The informal CCSP teacher practices that supported peer-drive learning were also visible throughout the school year in the ways teachers encouraged students to help and teach each other. For example, Mr. Torres's would often ask students to share their answers with each other to check if they matched rather than give a direct answer himself. When Albert was unsure about his calculations for latitude and longitude in a data-mapping project, Mr. Torres suggested he cross-check his numbers with Marisa (P.FN.4.25.12). When Marcos was unsure about next steps with a software program, Mr. Torres asked his neighbor to check in with him and help him out (P.FN.4.25.12). When Mr. Torres was working one-on-one with Rosa on her website html coding, they were struggling to troubleshoot changing the background and font colors. Instead of just taking over Rosa's computer and trying to figure out the code himself, Mr. Torres turned to Allison—who had successfully changed the color of her background and font—to share her html code with Rosa. He encouraged Rosa and Allison to work together to see if there was a difference between their html coding as a way to troubleshoot Rosa's problem (P.FN.12.14.11).

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Mr. Santos's informal CCSP practices encouraging peer-supported learning also included developing classroom norms for student collaboration to figure out answers instead of dependency on the teacher to say what was "right" or "wrong." Consider, for example, during a problem solving activity in which students had to figure out the weight ordering (from lightest to heaviest) of a set of bags with different labels (A, B, C, etc.) and unknown contents. When Mr. Santos noticed Larry sat separately from his group and wasn't participating, Mr. Santos asked him why he wasn't sitting with his group. Larry noted that they had already figured out the weight ordering. Mr. Santos then proceeded to switch the labels of the bags and while his students gave sighs of despair, Mr. Santos explained that he was switching them to see if Larry could demonstrate their group's problem solving process. When it became apparent that Larry didn't know how his group solved the problem and shared that his strategy was to figure out heaviest to lightest using a two-sided scale to compare them, Mr. Santos did not judge his approach as correct or incorrect, but instead asked his teammates, "Do you think there is a faster way?" Larry's group members nodded their heads and so Mr. Santos asked, "Can you show your different approach to Larry?" and then he walked on to work with a different group (C.FN.10.26.11). Mr. Santos regularly encouraged students to teach each other their different approaches and perspectives and never penalized students for sharing ideas or working collaboratively. The only behavior that Mr. Santos would not allow was for a student to complete a task for another student. For example, when Hyun needed help with html, James immediately came to his assistance. However, when Mr. Santos saw that James had taken over Hyun's keyboard and mouse, he called out from across the room: "Get off of Hyun's keyboard…just show him, don't do it" (C.FN.12.6.11). In this way, Mr. Santos used his pedagogy to create the contexts for peer-supported learning in computer science.

The results of these types of formal and informal CCSP practices resulted in animated classrooms full of the sound of students discussing projects, laughing together, moving from group to group with questions or suggestions, and sharing ideas with one another. Amidst the melee, teachers could be found rotating between groups, prepared to facilitate group work when there were conflicts or offer suggestions when teams were unsure about how to proceed. Thus, it was not uncommon to see students turn to each other for assistance on a regular basis, supporting each other's learning. For example, in Mr. Torres's classroom when students were creating Scratch animations, Belén was struggling to make her title page scroll up the screen. When she asked Isaac and Filipe for help, at first the boys teased her and said that she "should know." After they laughed together, Isaac and Filipe explained that all she needed to do was make the words an actual character whose movement she could control rather than text in the background of the screen (P.FN.2.15.12). On another occasion, Belén was the student to assist a classmate (Manuel) who wanted to make a character in an animation move from standing still to jumping up with its arms spread out. Belén explained that he could create two separate characters of the same person—one version standing and one version jumping up with arms spread out. In this way, he could make the character that was standing suddenly hide from view as the jumping version of itself would appear for viewers. Belén walked Manuel through this process (P.FN.1.20.12).

From assistance with small tasks (e.g., opening programs, logging in to systems, following steps, etc.) to assistance with larger tasks (e.g., solving problems, analyzing situations, troubleshooting, etc.), students regularly supported one another through learning computer science in these three classrooms. The CCSP practices focusing on collaboration described here,

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in conjunction with teachers' uses of humor (described in Chapter Seven), were key to facilitating the growth of positive classroom communities.

Impacts of CCSP: Students' Shifting Senses of Self in Relation to Computer Science

A review of student surveys at the three dissertation schools reveals that students were positively impacted by their experiences in their Discovering Computer Science classrooms, changing their perspectives not only about computer science in relation to the world, but also their abilities to pursue this field or related fields.

Numerous students reflected on learning about how computer science related to the real world. For example, when asked the question "How has your understanding of computer science changed as a result of Discovering Computer Science?" a Presidential High student replied, "I think that computer science can be used in my every day life" (P.S.29), while a City High student noted, "it was like a whole new world!! I learned so much things about the computer that I never knew before…that I thought I will never use in life" (C.S.14). Some Midtown High students explained, "Now I know more stuff I had no clue that involved technology or computer science" (M.S.8) and "Computer science is exploring computer science in general and to learn how we can use computer science in our every day lives" (M.S.5). Similarly, when asked to complete the sentence "Because of Discovering Computer Science I am…" a Presidential High student replied, "…more aware of the computer science that I can use in my life to help me" (P.S.6) while a Midtown High student stated, "able to understand more about how computers work and how they tend to have an impact in our lives" (M.S.5). These quotes suggest that the three teachers' methods of relating computer science to real life issues and students' interests had a valuable impact on students' understanding of why computer science was important to learn.

Students also seemed to describe a changing perspective about their own abilities with computer science that may be related to teachers' connected computer science pedagogy relating computing to real issues and social change. Students' self images as strong computer scientists came through when asked, "How has your understanding of computer science changed as a result of Discovering Computer Science?" A Presidential High student wrote, "I now understand how technology works, something I never thought I'd learn about, I went from not even knowing how to turn a computer on to becoming a top student of my DCS class" (P.S.13). A City High student replied to the same question saying "I respect it more. I admire the people that do it and my teacher" (C.S.5). Other students at Midtown High noted: "It has left me wanting to learn more" (M.S.6) and "That anybody can become a computer scientist" (M.S.14).

Similarly, when asked to complete the sentence "Because of Discovering Computer Science I am…" students described self confidence with computing, stating: "I am more of a problem solver" (P.S.8), "Better on computers and any other technology. I can teach other people what I have learned" (P.S.24), "The type of person that knows how to challenge herself when it comes to hard obstacles" (P.S.26), and "proud to be a female that learn a lot of computer science" (M.S.17). Many students who did not plan on pursuing computer science before taking this class even began mentioning their plans to study computer science beyond high school. Again, completing the same sentence "Because of Discovering Computer Science I am…" students replied, "Seriously getting more inspired and confident on my experience in computer science (as well as my major)" (M.S.4), "looking forward to seeing it more in college" (C.S.5), "more interested in working in a job that requires using computer and programming them" (C.S.10), and "Motivated to take this course in college as a major (maybe). I just know I want to

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learn more and do some work because of it" (M.S.12). At Presidential High, eleven of the thirty-five survey-takers mentioned wanting to take more computer science courses in the future.

The three teachers of Midtown, Presidential, and City High clearly demystified computer science for their students. Not only did the course material become more accessible to students over time, but students also began to see the impact of computer science on their every day lives and their roles as people who could change the world with academic knowledge. Students began to recognize themselves as people who could excel in the field while maintaining pride in their skills accumulated outside that field. The three teachers' CCSP practices powerfully engaged diverse students in computer science learning.

<u>Conclusion</u>

While connected computer science pedagogy appeared to have a positive impact on students in these three computer science classrooms, these teaching practices are not necessarily always easy to master and implement. Mr. Torres, Mr. Santos, and Ms. Mendoza shared important characteristics as educators who were *wanted* to connect computer science to students' interests, real social issues, civic engagement, and peer-support. All three teachers were able to develop a CCSP because they were willing: 1) to challenge their perceptions of traditional schooling hierarchies in the ways they recognized and valued their students' input, ideas, and perspectives; 2) to counter deficit beliefs that their students came from backgrounds or experiences un-relatable to computer science; 3) to spend time getting to know their students personal lives and interests so that clear connections could be made between students' real worlds and computer science; 4) to think creatively about computer science and its role in the social environment; 5) to discuss challenging topics related to race, socioeconomic class, the economy, jobs, etc. that related to students' personal lives; 6) to move away from traditional

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computer science education's programming-focus toward a focus on problem solving and computational thinking processes; and 7) to reflect on their ideas of computer science and teaching on a regular basis.

Furthermore, one must consider how the realities of public educational institutions impact teacher practice. The bureaucracy of administrators who fail to acknowledge the hard work their teachers are doing, the overwhelming responsibilities that have nothing to do with classroom teaching placed upon educators, and school cultures that often assume students cannot succeed simply because of the way they look or speak can all serve as major roadblocks to implementing a strong connected computer science pedagogy in today's high schools. External factors affecting classroom spaces must be acknowledged and addressed in order for teachers to be able to thrive at their craft.

Yet it must also be noted that teachers deserve more respect for the art of their craft and the devotion they have to their students. When teachers are respected by supportive administrators and colleagues who believe in their abilities to grow as expert educators, when teachers are dedicated to learning as they work and given the resources necessary to do so, when emphasis is on pedagogical actions and not just students' standardized test scores, then really powerful educators can evolve.

Despite the challenges facing their urban public schools, Ms. Mendoza, Mr. Torres, and Mr. Santos all demonstrated great skills at making computer science more accessible to a wider range of students while increasing access to this important field in our digital present. There is a lot that we can learn from their examples. One can only imagine what their connected computer science pedagogy would look like in more supportive environments where classrooms were never interrupted by administrators seeking help with their computers, schedules were never cut

short by unpaid furlough days enforced as a way to deal with budget cuts, and standardized tests were never treated as more important than computer science learning.

"Don't smile before Christmas":
Teachers' Uses of Humor in Computer Science Classrooms

"If you're really taking this stuff seriously, then you know how to laugh about it."
(Chad Hamrin, in conversation, 9/25/2012)

Introduction

Thus far I have described various pedagogical practices that teachers used to effectively engage students in computer science learning. From modeling computational processes to facilitating deeper thinking through provocative questions to using a connected computer science pedagogy (CCSP) that related computer science to students' interests, abilities to address social issues, and peer-supported learning, the three teachers of Presidential, Midtown, and City High School offered compelling examples of what computer science education *could* be.

Yet there was another important characteristic common to all three teachers—that I have not yet discussed—that proved essential to building learning environments in which computer science could come to life. Simply incorporating the pedagogical practices I have described thus far would not necessarily define a stellar computer science teacher. As one can imagine, just because a teacher explains that computer science relates to real life because computer coding was responsible for games like "Angry Birds" does not necessarily mean that this educator has effectively captured students' interests. In fact, there are numerous teachers across all disciplines who try to convince their students that, for example, learning English grammar will help them find jobs or Algebra really is important in life, but who still cannot seem to reach their students.

Indeed, simply going through the motions of the aforementioned pedagogical practices is not always enough. Rather, it is the development of the social context and the sincerity of human relationships built between teachers and students *in conjunction* with these pedagogical practices

that can help ensure a teacher's words reach willing ears. A theme that came up time and time again through this research was the value of using humor in the classroom. Humor served as an important pedagogical tool that teachers and students alike saw as essential to improving computer science learning.

A Brief Review of Humor in Education

Humor and laughter are often equated with a "lack of seriousness." Accordingly, teachers who encourage fun through joking are wasting time and taking away from student learning. However, numerous studies reveal that humor and laughter actually facilitate learning in powerful ways. Humor can: 1) assist with the **retention of new ideas** (Derks, Gardner, & Agarwal, 1998; Hauck & Thomas, 1972; Schmidt, 1994, 2002; Schmidt & Williams, 2001; Ziv, 1988); 2) **decrease student nervousness** toward improving test performance (Adams, 1972; Horn, 1972; Mechanic, 1962; Monson, 1968); 3) create an enjoyable classroom environment while **decreasing student anxiety about a subject** (Neuliep, 1991; Long, 1983; Smith, Ascough, Ettinger, & Nelson, 1971; Ziv, 1976); 4) **improve teacher-to-student relationships** by making teachers feel physically and psychologically closer, more accessible, and more responsive to students' needs (Crump, 1996; Gorham & Christophel, 1990; Wanzer & Frymier, 1999; Welker, 1977); 5) build **classroom community** with humor as an entry into embracing other cultural practices while controlling conflict between students (Cornett, 1986; Kelly, 1983; Wallinger, 1997); 6) **establish boundaries** while reinforcing positive, desired behaviors (Cornett, 1986; Kelly, 1983; Wallinger, 1997); 7) **motivate student learning** (Gorham & Christophel, 1992); and 8) **encourage creativity** through the playful thinking required to perform and interpret jokes (Moran & John-Stiener, 2003; Smolucha, 1992; Vygotsky, 1987).

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Returning to Vygotsky's (1978) point that learning occurs through social interactions between people, the importance of humor as an educational tool for improving interpersonal behaviors gains weight. Since sharing humorous experiences both establishes and maintains close relationships by helping to build trust, comfort, and commitment between people (Shiota, Campos, Keltner, & Hertenstein, 2004; Martin, 2007), the use of humor would be particularly important for students who may not know each other or the teacher, as well as in classrooms where students feel uncomfortable with the subject material. More specifically, in computer science courses that have typically been seen as boring and only for "computer geeks" (Margolis, et al., 2008), humor can help challenge stereotypes about CS while motivating interest and accessibility for diverse students.

Humor in the Dissertation Classrooms

Interestingly, classroom observations and interviews at Presidential High, City High, and Midtown High revealed that both teachers and students highly valued humor and joking. Among the forty-three students interviewed about teacher pedagogy at all three schools, thirty-six described their teachers as "fun," "funny," and having a "nice sense of humor" *completely unprompted* when asked: "How would you describe your teacher to a friend?" These same students explained that their computer science course was "fun," "interesting," and "not tiring you out" when asked: "How would you describe this class to a friend?" Six other students also emphasized that they valued their teachers' senses of humor, but when prompted with the question "Does your teacher ever make you laugh?" While this question urged students to reflect about humor, they were not required to agree that being funny was important. However, all six of these students explained that they valued their teacher's jokes when asked about laughter. Only

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one student did not mention humor at all during her interview, but still described enjoying the class. These trends are visible in the chart below:

Student Interviews and Humor

Describes Valuing Humor When *Prompted* 14% (6 students)

Does Not Mention Humor 2% (1 student)

Talks about the Importance of Humor *Unprompted* 84% (36 students)
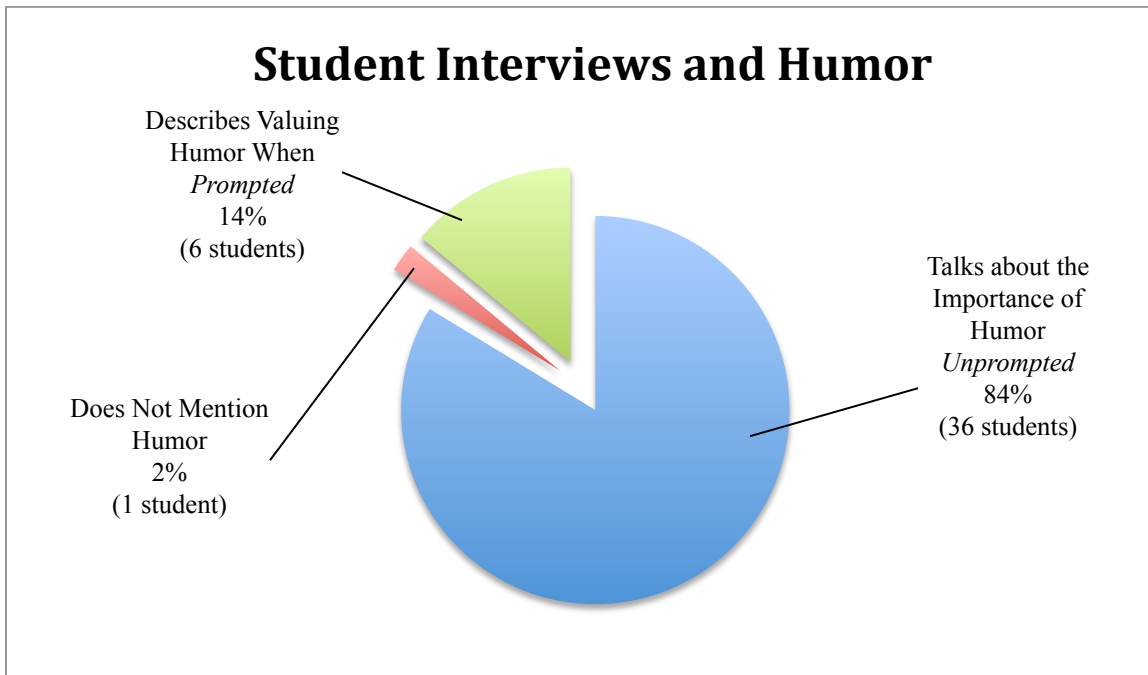
Figure 7.1: *Students' interview responses related to humor.*

Closer examination of field note observations and interviews showed that humor transformed computer science classrooms by 1) motivating student learning, 2) making learning less stressful, 3) building classroom community, and 4) mediating positive behaviors in disciplinary situations.

Motivation and Engagement

The use of humor in the classroom was particularly important for students who began the school year thinking that computer science was going to be inaccessible or boring. As Belén at Presidential High noted:

> I thought [Discovering Computer Science] was going to be boring and tough, but I realized when Torres teaches it, it was more fun….In class if it's boring, I kinda get tired with it…I don't do good. But when it's fun and more into it, then you'll be on the work and see what he's doing, what he's talking about. (Belén, P.Int6.5.9.12)

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Similarly, Belén's classmate Julieta told me that Mr. Torres's sense of humor made her "actually come to class," explaining: "I'm not gonna deny it, I used to ditch it…[but] the way he does stuff, it makes me want to actually learn more about computer science" (Julieta, P.Int10.5.11.12).

The importance of humor for engaging students who struggled with computer science rang true for Midtown High students as well. Juliette described herself as not particularly "good" at computer science and especially poor with the programming unit in which students created animations and games utilizing MIT's Scratch program. Despite feeling insecure with Scratch, Juliette was motivated to try programming after Ms. Mendoza shared a funny Scratch animation that made Juliette laugh. She noted, "[Ms. Mendoza] show[ed] us her Scratch project and I thought it was hilarious…when I saw it, I was like 'Oh my gosh! I wanna do that too!' So it *did* motivate me to want to do it" (Juliette, M.Int3.6.8.12). Ms. Mendoza's sense of humor effectively countered student discomfort with computer programming.

Similarly, Juliette's 11th grade classmate named Lena did *not* want to be in the computer science course at the start of the school year. She was uninterested in the subject and uncomfortable in a classroom filled with 10th and 12th graders who she didn't know. However, over time she became interested in computer science and began to excel in the class. Lena explained this was because she liked the teacher who made her laugh: "I think it's 'cause her personality is very happy…her jokes, they're funny...She always puts up a smile on everybody's faces" (Lena, M.Int2.5.10.12). I asked her why this was important and Lena replied, "it puts the student, like, me, in a good mood. Which makes me want to do the work." Clearly, the teacher's sense of humor facilitated Lena's entry into computer science, motivating her to want to do her assignments.

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Students' sentiments were no different at City High. As explained by Alejandra—a student who disliked computer science at the start of the school year—humor's motivational power translated into improved academic success. Being able to joke with the teacher was important "because otherwise I don't think my work would be as good as many other student" (Alejandra, C.Int10.5.23.12).

Of course, none of the three teachers were just coincidentally funny. Mr. Santos at City High intentionally kept his students laughing, comparing his pedagogy to the saying: "Luring bees, is best to do with honey than vinegar? Vinegar's not going to work" (C.T.Int2.12.15.11). Mr. Santos recognized that the use of humor yielded better learning results: "[When I] joke around a little bit more, I was able to get more out of them than with the structured, serious teacher that I was pretending to be [before]" (C.T.Int2.12.15.11). When Mr. Santos first started teaching, he tried not to smile too much because he was "told not to smile until Christmas" (C.T.Int2.12.15.11). But he realized that this made him "miserable" while having a negative impact on the students: "I was not as successful in getting the kids. I didn't get a lot of homework, and then they would start rebelling and I didn't get a lot of the work done, I didn't get good test results" (C.T.Int2.12.15.11). However, after Mr. Santos incorporated humor in his classroom, he realized, "it's not much of an issue if I insist on something, it has a tendency to happen easier than before….I think I've gotten more production from all my classes…they learn that I will be insisting on it, and I will be demanding, but I still enjoy their presence" (C.T.Int2.12.15.11). While many may believe that "fun" teaching is not "serious" enough, Mr. Santos provided an alternative perspective of his profession, revealing how teachers and students can actually appreciate each other's company instead of be neutral or in opposition to one

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another. Mr. Santos emphasized that teaching and learning can be something that both teachers and students *want* to engage in together.

Similarly, when asked the question "What do you think makes a really good teacher?" Ms. Mendoza at Midtown High immediately replied "HA! A sense of humor!" (M.T.Int2.6.14.12). Mr. Torres echoed this belief, noting that humor was a pedagogical tool that distinguished his classroom from others at his school which he thought were regimented and dull:

> They have several other classes where it's just very, "okay, sit down, and get to your studies." And I try to lighten up the mood for them because…I want this to be a class that they look forward to…the teachers that I remember the most are the teachers that made me laugh! (P.T.Int2.5.29.12)

While clarifying that you can't "have a comedy routine every time," Mr. Torres emphasized that "laughter is the best medicine" for engaging students with academic learning (P.T.Int2.5.29.12).

Indeed, students who struggled most with computer science showed increased engagement (defined as participation in activities and group discussion, eagerness to be called upon, etc.) when humor was used as a motivator. Manuel at Presidential High—who began the school year failing Mr. Torres's class—explained that he came to enjoy learning computer science because Mr. Torres was "different" from other teachers whose students were "falling asleep": "He's funny!...it helps me to learn…because I'm actually going to be there thinking" (Manuel, P.Int13.5.9.12). This was visible in Manuel's own behavior that changed significantly between Fall and Spring semesters. During the Fall semester, Manuel alone was responsible for forty of the 192 instances of student distraction (i.e. chatting, playing computer games, etc.) or disengagement (i.e. refusing to engage with class activities) that occurred in Mr. Torres's class. Manuel's disengagement included spending three whole class periods (a total of four and half hours) working on a *single* Powerpoint slide that was never even used in his group's final

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presentation. Furthermore, Manuel's constant distractions (particularly when chatting with classmates) resulted in Mr. Torres asking him to physically change seats on multiple occasions.

In contrast, Manuel only demonstrated *one* instance of disengagement/distraction during the Spring semester MyData Unit (see graph below). During this single instance, Manuel was playing video games when he wasn't sure how to use the computer data analysis software (JGR/Deducer). However, as soon as Mr. Torres assisted Manuel with the program, Manuel became an active classroom participant.
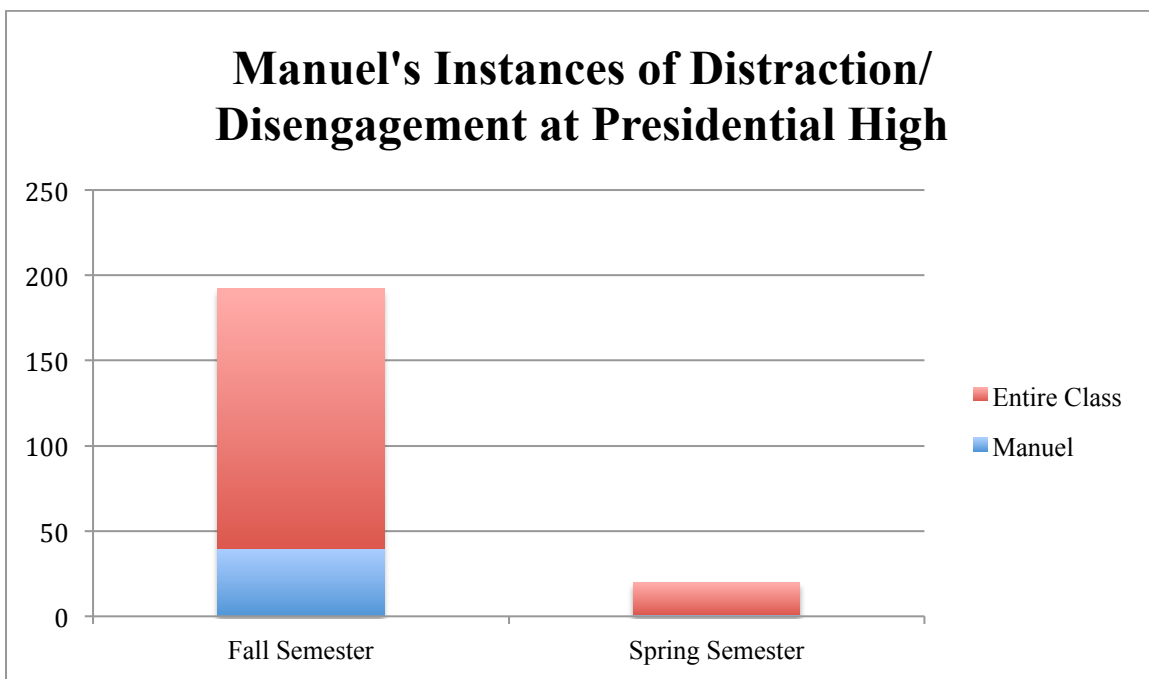
Figure 7.2: *Number of times Manuel demonstrated being distracted or disengaged at the beginning of the school year and by the end of the school year.*

The quality of Manuel's participation grew tremendously as he began contributing to whole-group discussions (i.e., offering eight different ideas over the course of one class period (P.FN.5.4.12)), volunteering to lead the teacher through creating a data subset in JGR/Deducer (P.FN.5.8.12), and even proceeding faster than his classmates with the JGR/Deducer program, asking his teacher impatiently, "What do we do next, Mister?" (P.FN.5.9.12). It's possible that Manuel's shift in participation was related to the subject matter being taught, however his

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interview suggests that his engagement grew because of the teacher's humorous pedagogy and ability to make learning fun. Manuel explained how he wouldn't be participating in a class that he found boring.

Reflecting on students like Manuel, Mr. Torres described how humor helped struggling students learn, noting "I believe it does work. I've seen a transformation from probably in the three years that I've been teaching ECS" (P.T.Int2.5.29.12). Mr. Torres explained how he used humor in this "transformative" way to show students that he was their "cheerleader" and "their number one supporter," thereby motivating student engagement with computer science despite the class taking place at 7:30 in the morning (P.T.Int2.5.29.12).

Yet what did humor as a motivator look like in Mr. Torres's classroom? Let us consider Brittany and Jessica's shifting engagement in whole-group discussions at Presidential High. At the start of the school year, neither Brittany nor Jessica seemed particularly interested in either computer science or Mr. Torres's class. These two girls alone were responsible for over half of all off-task behaviors during the first ten days of class and were often disciplined for chatting, disrupting class by trying to buy snacks from classmates, putting on makeup instead of participating in group work, or looking at videos/websites online. Furthermore, on four occasions during these first ten class meetings, Mr. Torres called on either Brittany or Jessica to share an answer during whole-group discussions, but neither student could come up with an immediate response. Brittany and Jessica's lack of engagement was particularly notable since Mr. Torres led ten, extensive, whole-group conversations during the first ten class meetings in which almost all other students participated. Even Gabriela—who sat with Jessica and Brittany—willingly participated without being called upon, whereas Jessica and Brittany refused to participate.

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On the eleventh day of class (September 21, 2011), an interesting shift occurred in Brittany and Jessica's participation as well as Mr. Torres's method of leading whole-group discussions. First of all, Mr. Torres began *consistently* integrating a sense of humor throughout the whole-group conversation in a way that he never had before. It is unclear why, but only during one previous class (on the tenth day) did Mr. Torres use humor to encourage student participation when discussing the dangers of trusting wiki sites (commenting how contributors could potentially share false ideas such as "Martin Luther King Jr. wore a peacock-colored Mohawk on his marches" (P.FN.9.9.11)). In contrast, on the eleventh day Mr. Torres incorporated six humorous comments as students shared their perspectives on technology-based communication methods. These, in turn, solicited playful comments from five students during the discussion. A lively conversation ensued which will be described in greater detail below.

Secondly, on this particular day of whole-group discussion, Brittany willingly contributed four ideas to the conversation, and Jessica shared her opinions on two different topics without being forced to participate. Both young women demonstrated a sense of pride in their ideas and increased comfort with talking in front of the class that was never shown before. In previous class discussions when Mr. Torres asked Brittany or Jessica to speak, neither student would reply. They would hesitate, look embarrassed, and fail to share ideas when spoken to. Yet when Mr. Torres incorporated a sense of humor into the class discussion, Brittany and Jessica transformed their participation. The details of this particular class are described below:

At the start of the class, Mr. Torres found out that Jessica was ditching. When he took attendance, he asked Brittany where Jessica was. As Brittany shrugged her shoulders, Belén blurted out, "But she's here!" because she had seen Jessica in an earlier class period. Mr. Torres took no disciplinary action, and approximately fifty minutes into the ninety-minute class period, Jessica arrived late without an excuse note. Mr. Torres did not scold Jessica and she sat down next to Brittany without comment.
Mr. Torres began a conversation about the various ways students choose to communicate in different life situations. He asked students how they would ask their parents' permission for

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something when they know that their parents would say "no." Mr. Torres asked his students, "For those of you who would say 'phone call,' why would you choose that?" Belén called out that she liked calling best because then you could hang up on your parents. Mr. Torres widened his eyes in mock horror, explaining with a smile that he could never do that to his mother. In response, Belén joked that you could rustle a bag of chips by the phone speaker and say that the connection was bad before hanging up. Mr. Torres laughed, then proceeded to act out this scenario while smiling slyly, holding an imaginary back of chips that he was crumpling next to an imaginary phone in his hand and saying: "Sorry…bad…con…ction!" Students laughed with him.

Suddenly, Brittany raised her hand and called out, "It's better face-to-face with your parents because texting is rude." Mr. Torres asked who in the class was really persuasive and Brittany mentioned that she was persuasive and that, "If you do it face-to-face, you can use a sad face and say 'Please!!!!!'" Brittany batted her eyelashes with a frown on her face, acting out how she would ask permission from her parents. As her performance solicited a laugh from the class, Veronica supported Brittany's idea, noting that you could express your feelings better in-person. Mr. Torres thoughtfully nodded his head and then asked, "Has anyone used *Facebook* with your parents?" Hector said that he did once and then Lissandro shared that he couldn't use *Facebook* because his mom labeled him as her son, adding: "So I can't do anything…" Lissandro's *Facebook* relationship with his mother caused some students to laugh, after which William pointed out, "You need to create a new one [account]!" Mr. Torres and his students smiled in agreement.

Mr. Torres moved on to describe a scenario in which one wants to share gossip, asking how students might communicate gossip. At that moment, Brittany was checking her makeup, so Mr. Torres turned to her and said, "So Brittany, let's put the compact away…how would *you* share gossip?" Without hesitating, Brittany replied, "I would just call." Pacho mentioned that he would gossip in-person and David shared, "I've seen it on *Facebook*, talking about other people." Mr. Torres asked, "Do these people have private status? Or can anybody see it?" Belén and David replied that it depends on the privacy setting of the gossiper. (P.FN.9.21.11)

This particular piece of the whole-group conversation shows how Mr. Torres embraced a sense of humor and playfulness at the start of the discussion, coloring the tone of how students proceeded to share their perspectives in the rest of the discussion. By acting out Belén's idea, students began to laugh and become more engaged in the conversation and immediately started participating. Even Brittany interrupted the discussion in order to share her own opinion about communicating with parents. Furthermore, picking up on Mr. Torres's dramatic interpretation of creating a poor phone connection with a chip bag, Brittany also used humor while acting out how she would manipulate her parents with a sad face and batting eyelashes. The openness to humor became contagious as visible in the *Facebook* conversation that ensued in which the class

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laughed together over Lissandro's *Facebook* dilemma and provided advice about how to avoid his mother online.

Also notable was Brittany's response to Mr. Torres when he asked her to "put her compact away." Instead of refusing to participate at the first sign of discipline, Brittany kept pace with the conversation, adding how she would communicate gossip. Yet, Brittany's participation did not stop here. As Mr. Torres continued to keep the class laughing through the whole-group conversation, Brittany also continued to share her perspectives regarding two other communication scenarios:

Mr. Torres asked students what communication method they would use for getting help with their homework. Brittany immediately called out that she would text while David said he would use *Facebook*. Mr. Torres nodded his head in agreement, but then suddenly smiled while rattling off using the tone of a radio commercial, "Or maybe you would come to Mr. Torres's after school tutoring on Mondays and Wednesdays from 3-5 for people who got D's and F's during the first month of school?" Mr. Torres's mini advertisement for his after school tutoring program made students laugh together. David suddenly turned to his friend sitting next to him and said in a suggestive tone: "William!" as if William needed to go to Mr. Torres's tutoring program. William gave David a mockingly annoyed look as David smiled.

Mr. Torres moved on to ask, "How about announcing that you saw someone famous?" Belén mentioned that she saw someone famous from "Shake It Up" when she went to a basketball game and that she immediately texted her sister and cousin. Mr. Torres asked if anyone else has seen someone famous. Brittany raised her hand and said she met Snoop Dog at a club. Mr. Torres asked, "Who'd you tell?" Brittany replied, "No one." After some other students shared about whom they had seen during their lifetimes, Mr. Torres described how he met George Clooney. Then he joked that in this particular city—where many movie stars live—locals understand that they shouldn't respond to famous people the way Wisconsin tourists might. Mr. Torres then proceeded to scream, "Oh my god! I met Magic Johnson!" while waving his arms wildly above his head and running up and down the center aisle like a crazed bird. Students all laughed loudly at his dramatization of an excited tourist as several others raised their hands vigorously to share about some other celebrities they had seen in the city. (P.FN.9.21.11)

In this excerpt, Mr. Torres's sense of humor continued to carry the conversation forward. Even more exciting was that Brittany's participation never waned as she shared her personal experiences.

The way Mr. Torres's sense of humor appeared to facilitate further student discussion continued into the next topic of conversation regarding how one might seek advice:

Mr. Torres called on Emilio, asking what communication method he would use to seek advice. Emilio said he would use *Facebook*, after which Mr. Torres asked the class if anyone would use *Twitter*. Belén proceeded to say "*Twitter* is *dumb*." William agreed, saying that it was silly to tell everybody about every little thing you're doing. Mr. Torres picked up on these students' thoughts, and added jokingly, "Do you need to know every second what's going on with someone?" and Mr. Torres acted out tweeting, while saying: "'I'm at the grocery store, then I am blowing my nose, then I'm going to the bathroom'? Could you imagine someone tweeting you from the bowl?" Mr. Torres's joke made students laugh. Jessica, who had never willingly shared her opinion in previous classes, then blurted out that *Twitter* was "stupidness" as Hector added that such a use of *Twitter* reflected "immaturity." (P.FN.9.21.11)

Mr. Torres used humor to build off of students' perceptions of *Twitter*. The idea of someone tweeting from the toilet caught the entire class's attention, not only starting a wave of laughter, but also motivating Jessica to share her personal reading of the scenario. Even though Jessica was late to class and had never contributed to whole-group conversations during previous class meetings, Mr. Torres's use of humor motivated Jessica to say her opinion aloud.

Interestingly, Jessica did not hesitate to continue sharing her perspectives as the conversation shifted to a more serious topic: How one might communicate mourning the death of a loved one. In what follows, students were able to shift quickly from laughing together to reflecting on how to deal with pain when someone dies. The class's openness to laugh apparently made room for students to be open about sharing more intense, personal feelings:

Mr. Torres asked students how they would mourn the loss of a loved one. Belén shared, "My aunt was pregnant and everything and then lost her baby at birth and then she posted on *Facebook* about it. Is that dumb?" William supportively replied, "It's not dumb. She's getting her feelings out…" Students suddenly became quiet and pensive as Mr. Torres said, "Well, let's think about mourning…what does it mean?" Clara raised her hand and said that mourning means "grieving." Mr. Torres asked the class what they do when they're grieving and students said that they usually show their grief and that they feel their personalities change. Mr. Torres asked what people wear and students said that they wear black. Then Mr. Torres noted, "So when you mourn, you miss them because you love them. So Belén described someone posting on *Facebook*. How do you mourn?" David said he would make a phone call and Mr. Torres nodded his head, then noted, "And some people like to keep to themselves." Belén responded to this

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saying, "It's bad to keep to yourself!" Jessica shook her head in disagreement and Mr. Torres commented, "Okay, Jessica disagrees…" Then, without being asked, Jessica explained aloud, "Why talk about it? It'll make you remember that person and you'll get emotional…" Mr. Torres replied, "Is it bad to get emotional?" Jessica said, "Yeah, because why cry in front of somebody? I'm not saying emotions are bad, but…" and Jessica's sentence trailed off. Mr. Torres nodded his head thoughtfully and then asked the entire class, "So do people agree?" Marisa noted, "It depends on the person." Emilio raised his hand and shared, "It's better to express yourself." Mr. Torres then turned back to Jessica and asked in clarification, "So Jessica, does it make you feel better to keep it inside?" Jessica responded, "I try not to think about it, try to push it out of the way." Mr. Torres replied, "Ok. There's no right or wrong, everybody deals with it differently." Then, without a pause, Mr. Torres asked the class: "What's the saying about taxes and death…?" to which David replied, "There are only two things you can't run away from: taxes and death." Mr. Torres and his students laughed together and Mr. Torres noted that he couldn't say it any better. Then Mr. Torres shared how he lost his grandmother who he was really close to and, even though it hurt to talk about her, he chose to talk about her more because it kept her memory alive. (P.FN.9.21.11)

In this excerpt, Jessica continued to engage in the conversation, pushing students to think about alternative perspectives. Immediately after sharing that she thought tweeting from the toilet was "stupidness," Jessica continued to follow the conversation about mourning the loss of a loved one without getting distracted. Unlike previous class meetings, Jessica did not hesitate to speak openly about what she believed regarding the importance of suppressing one's tears and sadness. Mr. Torres was quick to emphasize that there was no "wrong" or "right" way to mourn, thereby validating what Jessica had to share and supporting her participation in the conversation. Furthermore, Mr. Torres helped students lift out of the sad tone of their discussion by sharing a joke that pointed o the absurdity of life and death. This allowed students to smile again despite the potential melancholy of the conversation topic. Mr. Torres balanced this joke with his personal experience of losing his grandmother, further demonstrating how a sense of humor and willingness to share ideas could be woven together in these conversations. Humor became a tool for dealing with the tragedies of real life while discussing computing communication tools.

Jessica's engagement only grew after this conversation. When Mr. Torres asked "How would life be different if we could only communicate one-on-one?" Jessica was the first to share:

"It would be different…there would be no gossip" (P.FN.9.21.11). Later, Jessica even volunteered to read aloud and, when assigned the next activity, Jessica was the first to choose an activity topic for her group.

In all the above excerpts, Mr. Torres regularly built humor into the whole-class discussion, supporting a lively conversational space in which students showed new motivation to share their ideas, even when they disagreed with the ideas of other classmates. Within this context where humor was built into the whole-group discussion, students like Jessica and Brittany—who had never previously shown a desire to participate—were suddenly willing and even volunteering to speak. Humor served as a stepping-stone toward developing a conversational space that motivated student participation while validating student perspectives.

Yet humor wasn't only valued by struggling students. As Jason—a high-achieving student at City High—noted, Mr. Santos's "funny but interesting way of presenting a topic or concept to students…really helps you stay on task, to pinpoint exactly what you're doing…it gets you motivated for the subject while not tiring you out at all. You could literally listen to him talk all day" (James, C.Int3a.5.14.12). James explained that his teacher's sense of humor was motivational because "One, it definitely helps keep students awake, and two it literally gets you active and involved in things…you just can't help but soak up his energy, you know?" (James, C.Int3a.5.14.12).

This sentiment was echoed by numerous other students who explained that Mr. Santos's humor kept people from "falling asleep" (Maura, C.Int5a.5.8.12), kept "you more concentrated, not spacing out" (Olimpia, C.Int13.5.30.12), helps students feel that "it's not like work, just something you *like*" (Carlos, C.Int1.5.9.12), and "gives [students] energy to work" (Orlando,

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C.Int18.5.7.12). As Hyun aptly stated, "I feel more motivated, like, he's making us smile so I feel like I should do the work" (Hyun, C.Int14a.5.7.12).

Julio who excelled in computer science at Midtown High told me that he considered Ms. Mendoza was one of his top three favorite teachers of all time. He explained, "It's the jokes she makes, it's every little thing; it might be a noise, a picture, or something. She just knows how to make a joke out of it…she engages the class every day" (Julio, M.Int1.5.4.12). I asked him why this was important and Julio explained,

> I look forward to going to her class and then I want to learn what we're going to learn about too…I'm excited to know what she's going to teach that day….it will be a whole different story if she just engaged the class in a 'normal' way. (Julio, M.Int1.5.4.12)

Enrique, Julio's classmate, echoed this sentiment: "Her personality keeps me going, motivates me" (Enrique, M.Int11.6.11.12). Enrique explained Ms. Mendoza's sense of humor was particularly key in keeping him engaged since the class occurred at the end of the day when he was usually tired. Enrique described that Ms. Mendoza's jokes "gets me a bit more concentrated *into* it. It makes me keep on going" (Enrique, M.Int11.6.11.12). Other students also emphasized humor's motivational power, explaining that it helped students "pay more attention" (Xochitl, M.Int6.5.10.12), "helps a lot…makes your class better…make time pass" (Samson, M.Int4.6.1.12), "makes class to be interesting" (Jesenia and Natalia, M.Int12.6.5.12) because when a class is "boring you don't want to do the work" (Jesenia and Natalia, M.Int12.6.5.12).

The way humor motivated participation was visible in the ways Ms. Mendoza facilitated whole-group discussions. Early on in the school year, students did not know each other or want to volunteer their ideas without being called upon by the teacher. On one of these first days of class, Ms. Mendoza asked students to answer journal questions regarding their first, group assignment: "How will we ensure equality in our group? How have we progressed as a team in

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completing our project? What obstacles have we faced?" When students showed reluctance to share, Ms. Mendoza used her sense of humor to encourage participation:

When Ms. Mendoza asked for students' attention to share their journal answers, she noted "I want to hear back from every group—when you talk about equality, I don't mean just dividing the work, but also in terms of gender balance and race…" When students were silent in reply, Ms. Mendoza joked, "You're probably all thinking: 'Shoot! I gotta re-write this…'!" After two more minutes had passed, Ms. Mendoza then asked students to share their journal responses with the entire class. Julio raised his hand and said that equality meant "communicating with each other and being on the same page." Ms. Mendoza said this was great and asked who else wanted to share? No one responded.

Feeling the resistance to participate in discussion, Ms. Mendoza asked the class, "Do I need to call on people randomly?" The class collectively responded "Yes!" and Ms. Mendoza laughed, saying, "Okay…" then she gave an impishly playful smile while rubbing her hands together and said, "I *LOVE* calling on students randomly!" Students smiled and Ms. Mendoza called on Bernice first, who said: "Everyone is treated equally." Then she called on a male student who said: "Everyone comes together." Then she called on Samson who said: "No idea is wrong." Then Ms. Mendoza asked Irene: "Irene, how have you progressed as a team? Besides words like 'good'?" Irene replied "you should value each other…" but then Irene realized she wasn't answering Ms. Mendoza's specific question, so she added, "yeah…so, we've been getting to know each other…" Ms. Mendoza then asked; "What obstacles did you face?" Irene replied: "this guy is very distracting" and she pointed at Albert. Albert replied defensively with a smile, "I'm not even on your team!" Irene said in a flat tone, "oh yeah…" then added, "there have been no obstacles…I mean, we *do* tend to go into little groups…" Ms. Mendoza asked, "like cliques? Like within the group there's another group?" Irene said yes and then Ms. Mendoza thanked her for sharing. (C.FN.9.27.11)

In the above description of classroom discussion, students felt uncomfortable self-selecting to share their ideas. While Julio appeared comfortable enough to raise his hand and speak, the majority of the class asked Ms. Mendoza to call on them instead. Of course, the challenge of calling on random students is that the student called upon may have nothing to share. There may also be an element of apprehension at being called upon or not feeling ready when the teacher requests a response. Ms. Mendoza openly recognized this challenge when attempting to "break the ice" by looking slyly at her students and exclaiming in a mischievous tone that she "*LOVES*" randomly calling on students, jokingly acting like an evil tyrant forcing people to participate. In this instance, since none of the students called upon refused to share, it

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appeared that Ms. Mendoza's playfulness about "loving" to call on students may have helped

students relax in a way that facilitated their sharing. But of course, students' openness to share

may also be related to the way Ms. Mendoza respected students' desire to be called upon.

To clarify whether student participation in whole-group discussions might be related to

Ms. Mendoza's sense of humor, I began looking at how these discussions proceeded in following

class meetings. This revealed a shift between the previously described class discussion and a

class discussion the following week. While during the previously described class, students

needed to be called upon to share, the following week, students willingly shared their ideas

without needing the teacher to call on them:

Ms. Mendoza asked students to reply to the journal question: "How is information found on the internet? How is information shared on the internet?" As students began writing their responses in their journals, Ms. Mendoza announced, "Don't forget! You will turn these in for credit!" and then she gave a dramatic, "evil" laugh. Students smiled and laughed with her. After several minutes, Ms. Mendoza transitioned to a group discussion, saying, "So darlings, I know that some of you are still writing, so keep going but let's hear some ideas now. How do you search for *informacíon* on *el internet*?" Students giggled, and unlike the previous week, they immediately started calling out ideas such as: search engines, *Google*, *Bing*, *Yahoo*, and *Ask.com*. They called out the answers so quickly and openly that I didn't even have time to note which student said each answer. Ms. Mendoza wrote all of these ideas on the board, then asked students to share more examples. One student mentioned *Facebook*. Ms. Mendoza replied, "So, *social networking*," emphasizing this vocabulary term. Ms. Mendoza wrote "social networking" on the board, and then instead of writing "*Facebook*" she wrote "Facecrack," to which students burst out laughing in recognition of how people are addicted to using *Facebook* as if it were a drug like "crack."

After Ms. Mendoza's joke about "Facecrack," students proceeded sharing a number of other ideas such as *Tumblr* and *Flickr*, watching with rapt attention as she wrote their ideas on the board. Ms. Mendoza asked what kind of information was shared through Flickr, to which students replied "photos" and Ms. Mendoza exclaimed, "Yay!" Then, an English Language Learner/Special Education student sitting by the door, who was normally very quiet, mentioned *Wikipedia* as a website that is often used. Ms. Mendoza smiled while nodding her head, but then explained that, while this was not a social networking site, it was still useful to discuss. Then Ms. Mendoza turned to the rest of the class and asked, "what could it be called?" Another student shouted out, "search engine!" and Ms. Mendoza said it wasn't quite that, but instead an "open source site." As Ms. Mendoza wrote these ideas on the board (open source, Wikipedia, etc.), she asked the class, "So what does 'open source' mean?" A student called out "It's free to everybody" and then a male student in the back of the classroom added, "You can enter your

own text!" Ms. Mendoza agreed and added to the board next to "open source," the description "people can edit it."

Continuing the discussion, but trying to bring in other voices from the classroom, Ms. Mendoza then turned to her Spanish-speaking students and asked in Spanish, "If you need to look up the directions of your cousin's house in Riverside, what do you use?" Without pausing, some other students called out "*Google Maps*," and Ms. Mendoza repeated the question in English to the entire class, soliciting some other students to exclaim, "*Mapquest*!" and "*Google Earth*!" Ms. Mendoza noted that these were good, adding them to her list on the board. Then, turning to Irene (who seemed disinterested in the conversation and had started drawing a picture on a piece of paper), Ms. Mendoza asked, "Irene! You have a project due for Mr. Martinez. A video you have to recreate based on a scene from a book. Where will you share that info?" Irene looked up slowly and asked, "What?" Students laughed warmly and, without hesitation, started calling out: "*Youtube*!" and "*Myspace*!" As Ms. Mendoza wrote these ideas on the board, she turned to the class and jokingly asked: "Who still uses *Myspace*?!" Samson quipped back with a smile, "I do! I update my status!" and he laughed as the girl next to him asked, "Really?!" Then the two students laughed together. Through this laughter, the students seamlessly continued sharing different ideas such as *Google+*, email, *Twitter*, *Mega Upload*, and *Dropbox*. (M.FN.10.7.11)

In this class discussion, students willingly shared their ideas without being called upon by the teacher unlike the previous class discussion just one week before. How was it possible for students to gain such comfort with sharing ideas in whole-group discussion over just one week? One might argue that these journal questions may have been easier for students to answer compared to the previous week's journal questions. However, the ease of a journal question would not necessarily motivate excitement to share. Indeed, students' excitement to share—as they shouted ideas faster than the teacher could call on them—appeared to be facilitated by the teacher's sense of humor in the way she framed the discussion. First of all, before even asking for answers, the teacher jokingly warned students that she would be grading their journal responses. While normally grades make students feel uncomfortable, students responded to her comment with laughter, suggesting a level of comfort with the teacher and removal of any foreboding that may accompany doing a common, class assignment. Secondly, Ms. Mendoza solicited student answers by brightly calling them "Darlings" (a term rarely heard in high school classrooms) and switching between English and Spanish in a playful manner. Ms. Mendoza's

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request for students to share ideas was therefore colored with a sense of fun that, one could imagine, would contrast greatly from a teacher who might stand at the front of the classroom and ask in monotone: "Alright students, how do you search for information on the internet?"

It is also notable that students' energy and motivation to share never diminished over the entire discussion. Ms. Mendoza's continued use of humor to facilitate the conversation seemed to sustain student participation. When Ms. Mendoza joked about "Facecrack" and laughed about how people don't use *Myspace* anymore, students stayed engaged and even joked back, as Samson claimed that he continued to update his *Myspace* status and his classmate questioned this statement. Even an English Language Learner/Special Education student (who had been silent for all previous classes) shared an idea with the class.

Of course, one student—Irene—still seemed generally detached from the conversation. However, no other students showed this kind of disengagement and you could sense a high energy in the room as students called out their answers around Irene without needing to be coaxed. Furthermore, Irene's disengagement when replying "What?" to Ms. Mendoza during the class was met by non-judgmental student laughter. Student laughter and Ms. Mendoza's refusal to discipline Irene or stop the flow of the conversation seemed to quell any tension that may have arisen from Irene's resistance without triggering further negative behaviors. The response of students and teacher alike demonstrated a sense of familiarity with Irene's resistant behavior, suggesting that it was not uncommon for Irene to respond as she had and, perhaps, even part of a common "act" that Irene regularly performed. Overall, it appeared that Ms. Mendoza's humor and willingness to laugh kept class discussions lively and students engaged.

Countering Stress: Humor Makes Computer Science & Teachers More Accessible

Previous work by Berk and Nanda (1998) revealed how humor decreased stress levels and countered students' negative perceptions of a college-level statistics course. In a similar way, students at my three dissertation schools described that humor decreased stress by making teachers and computer science feel more accessible. For example, David at Presidential High noted that laughter made learning "less stressful and you get more confident with the teacher…You actually open up a little more" (David, P.Int2.5.7.12). David's classmate, Allison, emphasized this as well, noting how Mr. Torres's humor made the classroom feel "comfortable" which, in turn, made her "actually interested in doing the work" (Allison, P.Int16.5.8.12). Ruby—a high-achieving student at City High—also explained that she enjoyed Discovering Computer Science because Mr. Santos's sense of humor made it less stressful than other classes. She was able to excel in computer science because, "there's not a lot of pressure…it's more relaxed…[you can] have fun but work at the same time" (Ruby, C.Int6a.5.3.12).

Indeed, numerous students expressed that teacher humor could "make their day feel better" (Nico, M.Int8a.5.11.12), create "a good environment in order for everyone to feel good" (Joseph, C.Int11.5.10.12), and make students feel more "comfortable" so that they "pay more attention" in class (Eddie, C.Int9b.5.30.12).

Even Ms. Mendoza emphasized that humor counters stress in the learning process by making abstract concepts feel within reach. This was especially important for young women and students of color who may have believed they could not do computer science because they didn't "fit in" with a field dominated by white and certain Asian men. As Ms. Mendoza explained:

> I think about some of the students that came in and may have been a little bit intimidated with the idea of computers and everything was just kind of weird and this was obviously a man's thing. And to see my girls now…they're willing to say what their solution is, even if it's wrong. And I think that's where the real learning comes in because it's

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breaking those stereotypes and those barriers. And I think that's more important than remembering what html stands for. (M.T.Int2.6.14.12)

In this conversation, Ms. Mendoza emphasized that humor helped students gain self-confidence working with abstract ideas by allowing them to laugh at mistakes, ask questions, share answers, and figure out solutions to computer science problems. Without humor's power to relax the learning environment, Ms. Mendoza believed students wouldn't have persisted when faced with computer science challenges.

In the classroom, Ms. Mendoza regularly used humor to acknowledge that computer science might feel scary *but* that students were capable of excelling through a positive outlook. For example, consider how Ms. Mendoza introduced web design, employing her sense of humor to both motivate student engagement and soothe students' fears of html coding:

Ms. Mendoza instructed students to close their laptops and bring their attention to the front of the classroom. Students hesitated, to which Ms. Mendoza replied, "Don't worry, your computer knows what to do…" She laughed as several students smiled with her. Then she told them "Open your journals. We're going to take quick notes on web design." Ms. Mendoza erased the front board and said, "When we look at web pages, they look really cool and sweet. This is what we see…" and she pointed to her blog webpage projected on the front board. Ms. Mendoza continued, "But how are these designed?" Albert replied "Java script." Xochitl called out "I don't know!" Ms. Mendoza agreed that Java script was one type of language people could use, but then she asked students, "Do you think they just grab stuff and put it up?"

Ms. Mendoza then projected a webpage that she told students she created for fun during the summer. Students laughed as they looked at the page: It was titled "Cooler than the other side of your pillow" and had a light blue background, a picture of a llama wearing a scarf, and a couple of silly sentences located at the bottom of the page that were unrelated to the llama. Ms. Mendoza showed students how you could click on a link at the bottom to see when the last viewing of her website happened. Then she explained that she coded everything, from the name that popped up at the top of the web browser to the title to the background. She explained, "You see this cool llama picture and everything, but behind the scenes, there is code that looks like this…" and then Ms. Mendoza projected the html code for her web page so everyone could see it.

When the html became visible on the front screen, several students made gasping sounds as if they were nervous. When Ms. Mendoza asked who had gasped, students pointed to one of the girls in the classroom. Ms. Mendoza then replied, "Huh! Interesting that it came from a female…why do you think that is? A lot of females think they can't do this stuff. But we can! *I did it*!" Students smiled.

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Ms. Mendoza continued, "So we're going to take notes. You've all seen this on web browsers. Anyone know what it means?" and Ms. Mendoza pointed to the word "http" on the board. Larry started to reply, "Home…?" at which point Samson interjected, "Home To The People!" Ms. Mendoza laughed with Samson and several other students, then wrote the definition for "http" on the board, explaining: "Hyper Text Transfer Protocol." But as she started writing "Protocol," Ms. Mendoza giggled and told students that she needed help spelling that word. Students laughed and helped her, after which Ms. Mendoza thanked them. Next, Ms. Mendoza went over the concept of "tag" and said, "We know what tags are from *Youtube* or *Twitter*, but in web design, *these* are tags…" and Ms. Mendoza pointed to the lines of html text in her web page code that was projected on the front screen. She told students that the tags tell the computer what the web page should be, and then she wrote the definition for "tags" on the board: "Instructions for how a web page should look like." Pointing to the line that started with "<body>" in her html code projected on the front screen, Ms. Mendoza continued, "So <body> tells the web page what will be in the body of the page." Students, fully engaged, wrote these notes in their journals. Then Ms. Mendoza asked her students what they thought the term "html" meant. Sung Woo called out, "It looks like 'hotmail'" and Samson laughed while Ms. Mendoza smiled in recognition of Sung Woo's contribution, then she wrote the definition on the board: "Hyper Text Mark-up Language" and explained that it was a language used for building web pages.

As students wrote this definition in their journals, Ms. Mendoza pointed to the lines in her html code starting with "<html>" and "<head>" and asked "So what do you notice about these tags?" Sung Woo said "there's a slash…" and one of the female students called out "It's where things start and finish!" Ms. Mendoza praised them, adding, "So with a new tag, you always need brackets so that <title> means begin the title" (which she wrote on the board) "and then </title> means…" But before Ms. Mendoza could finish her sentence, Irene—who had been disengaged with her head down since the start of class—suddenly called out "where you end the title!" Ms. Mendoza looked joyfully at Irene and said "Yes!" and then wrote this definition next to "</title>" on the board. Ms. Mendoza then added, "So you have to be very specific with the computer when you're telling it what to do." Ms. Mendoza reminded students that this specificity was similar to a previous activity in which they practiced giving exact directions for making a peanut butter and jelly sandwich. Then she told students, "So we're going to get started with just the basics. Don't be afraid to make mistakes! The best websites involved tons of mistakes. Do you think Thomas Edison made one light bulb and that was it?" Sung Woo smiled and said "Nooooo!" and students laughed as Ms. Mendoza instructed them to sketch out their ideas for a personal web page they would want to design. (M.FN.1.13.12)

Ms. Mendoza infused her web design lesson with light-hearted humor that served to make learning less stressful. Even before the web design lecture began, she joked about computers "knowing what to do" when closed, motivating student compliance with her directions. Similarly, by introducing html web design with her own humorous website as an example, Ms. Mendoza set a playful tone for the lesson while modeling how students could have

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fun designing webpages. Yet students were intimidated by the look of the html code. Many teachers would have ignored students' gasping at the code, but Ms. Mendoza openly recognized the tendency for females to feel apprehension around computers while pointing to herself as an example challenging such fear in a way that made students smile. Then, using a sense of humor to point out that she needed help spelling "protocol," Ms. Mendoza gave students an opportunity to feel like experts while actually demonstrating that you do not need to be perfect at everything (e.g., spelling computer terms) in order to make a web page. By showing her own vulnerable side in a way that made students laugh, Ms. Mendoza took the opportunity to help students relax about their own potential mistakes or lack of knowledge.

Ms. Mendoza's openness to joking also seemed to welcome student creativity through humor while learning web design vocabulary. Students like Samson felt able to joke that "http" could stand for "Home To The People" and Sung Woo felt comfortable pointing out that "html" sounded out "*Hotmail*." Rather than disciplining students for making silly remarks, Ms. Mendoza laughed with her students, welcoming these creative interpretations of web design vocabulary in a way that encouraged students to relax with a potentially intimidating topic. Students' playfulness with web acronyms did not take the lesson off-course, but demonstrated their engagement. Even Irene—who had her head down—wanted to share that incorporating a slash in the html code for "title" (i.e. "</title>") meant to end the webpage title. Then, pointing out that making mistakes was okay while learning html with a joke that even Thomas Edison made mistakes when inventing the light bulb, students were able to smile before proceeding. Humor counteracted the stress of learning an abstract web design language while encouraging creative ideas.

Mr. Santos also used humor to decrease stress in the classroom. He rooted this practice in the belief that his best teachers "were people that I felt comfortable [with], they were people that I felt I could make a mistake and not be, you know, humiliated or made feel less…they were people that I could joke with and still keep a certain professional relationship" (C.T.Int2.6.4.12). Putting these beliefs to practice at City High, Mr. Santos used humor to counter stress and motivate engagement with computer science by inserting joking comments throughout class. For example, on the very first day of class, students seemed anxious and the air felt heavy with both September heat and the exhaustion of returning to school. In response, during the very first minutes of class, Mr. Santos greeted his students by saying, "I hope you had a great summer! I know that I did. And to be honest, it was so good that I didn't want to come back!" and then Mr. Santos laughed (C.FN9.1.11). While this comment wasn't gut-wrenchingly funny, Mr. Santos showed his students that he was open to laughing while empathizing with their general apprehension about returning to school. This sense of humor continued into his next sentence in which he addressed his students as "ladies and germs" (C.FN.9.1.11)—which received some chuckles from the students—and as he proceeded to apologize for the way he would be taking attendance, noting: "Sorry if I massacre your last names. My Spanish is terrible" (C.FN.9.1.11). Students burst out laughing, recognizing that Mr. Santos's first language was Spanish. As Mr. Santos went over a course syllabus and class rules, he took the stress and boredom out of such tasks by joking about keeping mobile phones away to refrain from "chismosos or chismes" (meaning "gossip" in Spanish) (C.FN.9.1.11) and referring to the "grades" section of his syllabus as "the fun part" (C.FN.9.1.11). Several students laughed rather than tensing up about responsibilities and rules. While these actions were small, they effectively kept students smiling, taking the anxiety out of the first day of computer science class.

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As Mr. Torres and Ms. Mendoza demonstrate, teachers do not need to be expert comedians in order to help students counter stress with laughter. Simply showing an openness to un-offensive playfulness while using humor to acknowledge stressful moments effectively reconnected their students to the learning at hand while making computer science seem less elusive.

Building Community Through Laughter

Related to the ways humor decreases stress is its ability to eliminate tension between people, supporting friendships among teachers and students in a classroom community. More specifically, Darrel noted that humor improved student learning by establishing positive relationships between students and teachers:

> I think that you learn better from teachers that you like better…teachers that I felt were not as likeable, not as approachable, it's a little bit harder to learn. But when you know that the teacher that you have is someone that you like as a person, then I think it makes it a bit easier to be yourself in the classroom and not be worried about something else that could be distracting to you. (Darrel, C.Int2.5.30.12)

Darrel's point is especially salient for students who are intimidated by computer science; having a computer science teacher who feels approachable can make asking questions or making mistakes less overwhelming. This was expressed by Maura who noted that "bad" teachers are "really strict" instead of funny which is "a bad thing because I think you get scared of that person and it affects your learning…you don't know if this is right…and then you're scared to ask questions" (Maura, C.Int5a.5.8.12). Ruby echoed this idea: "If a teacher is more uptight, you feel you have to stay quiet and try not to interact with people to try not to upset the teacher" (Ruby, C.Int6a.5.3.12). Instead of being fearful of "upsetting the teacher," Alberto pointed out that his teacher's sense of humor "helps you because if he makes you laugh and jokes around with you, then you have more confidence to go and talk to him, like 'Oh, Mister, could you help me out

with this?'"(Alberto, P.Int3.5.8.12). Humor can facilitate learning by making teachers more approachable, making it easier for students to ask questions when they don't understand a new idea.

This "approachability" through humor was especially important for English Language Learners like Gustavo who felt uncomfortable asking questions in a new language. Gustavo pointed out that his Mr. Santos "tried to make [learning] fun in a way…by his joke" (Gustavo, C.Int12.5.30.12) that were often in both Spanish and English. This humor helped Gustavo learn computer science because "it makes me feel comfortable in the class…I can talk to him…I can ask question" (Gustavo, C.Int12.5.30.12). Among ELL and English-speakers alike, humor's power to make teachers more approachable was a recurring theme.

Other students repeatedly commented on the ways humor helped them feel "comfortable." Ricardo explained how joking was a "comfortable thing the teacher can do…to get involved with the individual to learn the subject and the programs in this computer science class" (Ricardo, C.Int8a.5.4.12). Xochitl noted that Ms. Mendoza's sense of humor "helps us learn and feel comfortable" (Xochitl, M.Int6.5.10.12). This comfort related to a sense of belonging. Enrique shared that Ms. Mendoza regularly made him laugh "And that really gets us more *into* this class and makes us feel welcome into particular environment…wanting to stay here more" (Enrique, M.Int11.6.11.12). Allison compared this sense of belonging to how one feels in a "family" where "everybody just laughs. Nobody is criticizing nobody" (Allison, P.Int16.5.8.12). She noted "It feels good because everybody could laugh at you if you make a mistake, but in a good way…[it] makes you feel like you're home" (Allison, P.Int16.5.8.12).

Students directly translated these feelings of comfort and belonging through humor to the ways humor also affected their perceptions of teachers. Students began to see their teachers more

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as "friends" rather than distant authority figures, and the classroom became more of a "family."

For example, Lissandro at Presidential High emphasized how Mr. Torres's sense of humor built

a special kind of rapport: "He be fun. He takes jokes. He's a friend to us" (Lissandro,

P.Int12.5.23.12). Similarly, Darrel described his teacher—Mr. Santos—as "very funny. He's

one of those teachers that I feel like I can just always talk to…I think he's a good friend to many

of the students here" (Darrel, C.Int2.5.30.12). Students in Ms. Mendoza's class reacted the same

way to her sense of humor that "makes it feel like she's a friend…because she's trying to make it

fun" (Annie, M.Int10.6.1.12) and "I sometimes see her as another classmate!" (Guillermo,

M.Int9.6.1.12). The powerful bonds between teacher and student that humor facilitated were

explained by Julio as well: "I really don't like building a friendship with teachers, but then

sometimes it just happens…So I'll put her in the top three of favorite teachers I've had

throughout my whole life" (Julio, M.Int1.5.4.12).

Interestingly, Hyun described that Mr. Santos's humor and approachability as a "friend"

facilitated his process of becoming part of the classroom community:

> When I first came to this class I was kind of quiet. Just like, do my own work, no group
> activities until he kind of opened up to us. And we were watching some videos on
> *Youtube*…the music was really funny, and after that I felt like I could be more friendly to
> him, like a friend. And so, I sort of opened up…I got more into the stuff he does. And
> everyone. (Hyun, C.Int14a.5.7.12)

Here Hyun describes how not only his view of the teacher shifted, but also his view of his

classmates could shift through Mr. Santos's humorous use of *Youtube*. Hyun began to see his

teacher as a "friend" which, in turn, increased Hyun's interest in "everyone." Hyun expanded on

this by describing how his teacher's humor facilitated community-building across linguistic

barriers. Hyun—whose first language is Korean and who doesn't speak Spanish—noted that Mr.

Santos sometimes "makes jokes in Spanish and it's really funny because there's a lot of Hispanic

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kids here and sometimes if I don't understand it, I ask them to translate. And when I get it, it's really funny and that makes me laugh" (Hyun, C.Int14a.5.7.12). Hyun shared that this gave him more reason to communicate with classmates in an effort to know why people were laughing. In this way, Mr. Santos's friendly humor facilitated positive, cross-cultural engagement between students in the classroom.

Indeed, teacher humor facilitated bonding between students as Carlos explained, "we just feel more connected…so if we need help we just ask [each other]…if you wanna be friends, then we're cool" (Carlos, C.Int1.5.9.12). David shared how positive teacher-student interactions through humor could spread to student-student interactions: "if one student sees me…speaking to the teacher in a certain way, maybe he'll get that sense like, 'Oh I can be the same way, I could have the same connection with the teacher'" (David, P.Int2.5.7.12).

The importance of such a "connection" was emphasized by students like Lena who did not want to take computer science. Lena initially felt uncomfortable in this class because she didn't know many of her classmates. She explained, "when I got to the class at the beginning, I felt like, 'Oh no. I'm stuck here.' And I actually did want to change [classes]…[but] it changed definitely because I got to interact with [other students]…I think that [Ms. Mendoza] knows how to bring in everybody together" (Lena, M.Int2.5.10.12). Through humor, Ms. Mendoza created a welcoming classroom environment in which Lena eventually became a stellar student and close friend to many of her peers.

Interviews with all three teachers at these different schools revealed that the use of humor to build positive relationships was completely intentional. Mr. Torres explained that humor provided a way to find "common ground," facilitating a healthy classroom community:

> I think when you find common ground in a classroom to establish that class, that's when that classroom community starts to develop. And when they see you more as not just a

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teacher, but as someone who is working in their best interest that level of trust starts to increase…so those personal connections, the laughter, that all helps…Because they're part of something now and they don't want to let their classmates down or their teacher down either, or themselves. (P.T.Int2.5.29.12)

This sentiment echoed students' comments about teachers as "friends" and their computer science classes as "family."

Mr. Santos at City High emphasized that joking helped build comfort with both each other and also the material being learned:

I joke around with them…and they joke around with me…So I think we are pretty comfortable as a team…that's how I get them to agree to go into deeper thinking and stuff like that because they know I'm not going to jump on them or beat them up for the wrong answer. (Santos, C.T.Int1.12.15.11)

Building a "team" through humor helps students feel open to trying more challenging computer science activities.

Ms. Mendoza also believed that a sense of humor facilitated building positive relationships in the classroom: "[It] goes back to what makes good teaching is having that connection with your student…the fact that you build some sort of solid relationship, it allows them to grow as an individual…that's where the real learning happens" (M.T.Int2.6.14.12). As noted earlier, Ms. Mendoza went on to explain that "real learning" refers to students breaking stereotypes about their ability to try and excel in fields like computer science. In this way, Ms. Mendoza emphasized how using humor to build positive relationships can support students' beliefs in themselves.

At Midtown High, a friendly community grew over time as teacher and students alike embraced humor as a central communication tool. Consider, for example, this typical day in Ms. Mendoza's computer science classroom:

As the second bell rang marking the beginning of class, Ms. Mendoza stood by her open classroom door, greeting each student with a firm handshake. As she shook each student's hand,

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she would look that student straight in the eyes with a bright smile, greeting her or him by name. At one point, a student named Andrea gave a weak handshake in return. With dramatic flare, Ms. Mendoza refused to let go of Andrea's hand and pulled her back in the style of a ballroom dance move while exclaiming, "Oh no! You need to give me a proper handshake! Let's try again!" Andrea smiled shyly, but willingly shook Ms. Mendoza's hand again with a firmer grip. Then, Andrea and Ms. Mendoza started laughing together.

Once everyone had found a seat in the classroom, Ms. Mendoza greeted her students like an M.C. prepping a crowd for a rock concert, shouting "HELLO MY COMPUTER SCIENTISTS!" Students laughed and smiled, shouting loudly in return: "HELLO!" Without a moment's hesitation, Ms. Mendoza asked her students "So what's the good news? Anybody want to share?" Julio called out with a smile: "What's *your* good news?" Ms. Mendoza's eyes squeezed shut and she grinned brightly as she explained that she was really happy because, even though she normally teaches the middle school students, she got invited by the senior class to attend their bonfire at D--- Beach tonight. Then Ms. Mendoza clapped her hands together and got the whole room applauding her "good news." As the applause died down, Juliette raised her hand and shared, "This weekend is a three-day weekend!" The entire class immediately burst in applause and students started to laugh together. Ms. Mendoza then asked Andrea to share some good news, and Andrea replied in a gentle voice, "It's Friday!" Ms. Mendoza repeated "It's Friday everybody! Let's give a round of applause for Friday!" and students clapped and laughed.

Following these greetings, Ms. Mendoza pointed to the day's agenda written on the side-board of the classroom, explaining that students would be sharing their blogs with each other, uploading links and images to their blogs, and then beginning to learn how to create their own websites. With an animated tone, she exclaimed about how excited she was that students would be making websites, but as she said this, Irene put her head down on her hands. Ms. Mendoza laughed and said, "Irene! Please don't fall asleep today!" Irene kept her head down without replying, and her classmates looked at her, smiling. As Ms. Mendoza began directing students to pick up a laptop from the class cart, Xochitl and Shari arrived late to class. Ms. Mendoza swung herself around and asked dramatically, "Why are you late!?" Shari replied that they weren't late, to which Ms. Mendoza pointed to the clock that showed it was 1:45, explaining that class began at 1:40. With a laugh from across the room, Samson declared, "It's 1:40 somewhere in the world…!" and Ms. Mendoza and several of the students smiled together. After this, the two, late students moved slowly across the room, eliciting a joking question from Ms. Mendoza who asked them if they were constipated because they were walking so oddly while also being late. At this question, Xochitl laughed and said that she *was* constipated, and as she sat down Ms. Mendoza, Xochitl, and several other students laughed together.

As students settled at their desks with laptops, Ms. Mendoza wrote "wordpress.com" on the board and directed students to login to their blogs at this website. However, she gave Lena separate instructions, telling her to go to "sharklasers.com." Lena smiled and typed this address into her web browser. She immediately started laughing, eliciting a smile from Ms. Mendoza as her classmates at her table asked to see what the website was about. They soon found that the "sharklasers" website was a spam-fighting technology site with a funny picture of a shark, under which was noted: "Beware of sharks with laser beams attached to their fricken heads." Lena then opened up her blog site while chatting with the other students at her table.

Over at Nico's table, several students started congratulating him on running a half marathon last weekend. Rather than scold students about chatting, Ms. Mendoza joined the conversation, asking Nico how it went. Nico explained that he was practicing an 11-mile run

tomorrow. Ms. Mendoza encouraged him with these efforts. Then Ms. Mendoza cleared the front whiteboard and instructed students to come up and write their blog addresses on the board so that classmates could search for them and subscribe to their blogs. As students wrote their blog addresses on the board, Ms. Mendoza often laughed at the creative and funny titles students had come up with, to which students would proudly point out which address name was theirs and laugh with each other. Then, Ms. Mendoza projected her own computer screen at the front of the room, modeling the process of "subscribing" to other people's blogs. Students quieted down to listen to her instructions as she showed them where to go on the blog website. She chose one of the blog addresses a student had written on the board and said "So some very mature person has the URL called 'XXX69'…" to which students (including the creator of this blog address) started laughing. Ms. Mendoza smiled with her students and added, "I thought it was going to be *cocino* or 'PERV' instead, but…" which got more students laughing with her. Ms. Mendoza then demonstrated how students could subscribe to this blog as students followed along. Ms. Mendoza began walking around the room to assist students who were having difficulty with this process. One student's computer wasn't registering the blog URL due to an administrative issue on the computer's password controls. Ms. Mendoza had control of these administrative passwords through her own, teacher laptop, so she proceeded to unlock the student's computer from her teacher laptop without telling the student. When the student's computer started working suddenly, she looked up at Ms. Mendoza and exclaimed, "It's working!" and Ms. Mendoza replied, "It's my magic touch! Give me sunshine arms!" and she held her arms up above her head, wiggling her fingers in a way that made this student and several others start to laugh.

Ms. Mendoza then gave students about ten minutes to look at each other's blogs and subscribe to them. Larry pointed out that he was impressed how Sung Woo already added images to his blog. Ms. Mendoza looked up, congratulating Sung Woo on being "ahead of the game," and Sung Woo smiled. Students were engaged with this activity, but also chatting with each other. At a table that included Samson, Lena, Albert, Irene, and Larry, students were joking and laughing together as they worked. Larry was playing music with his cell phone at a very low volume, to which Irene suddenly asked "What's that song?" Larry acted like there was no music playing and replied, "What song?" as he glanced up at the ceiling the way a cartoon character does when pretending not to be doing something suspicious, and then he turned off the music. Irene called out "Is that Katy Perry?!" to which Albert said in an incredulous voice, "Who listens to Katy Perry?!" Irene then asked, "Didn't you hear it?" and Albert continued Larry's joke, pretending that no music was playing and asked in a voice that mimicked concern, "What are you *on*?" Then the table burst out laughing together. Irene gave a half-smile and told Albert "Stop being such a *troll*!" (since his blog address was "Troll"[1]), to which Albert jokingly asked, "What's a troll?" Irene then jokingly replied that Albert should beware of "Mac" who has a "horse face and wears ugly green sweaters and eats trolls." Alex widened his eyes in mock horror and then the group of students laughed together at the silly exchange. Then Samson interrupted and asked for someone to help him change the background color of his blog page, to which Albert got up and showed Samson how to do this on his computer.

Ms. Mendoza continued walking around to check in with students, but then returned to her desk to upload a new image to her blog. Then she told students to check out her blog and leave a comment. The image she added was a photo of herself with a huge smile, pointing

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[1] According to the *Urban Dictionary* online, "Troll" is defined as "One who posts a deliberately provocative message to a newsgroup or message board with the intention of causing maximum disruption and argument" (Urbandictionary.com, 2002).

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downward. Her pointing finger directed students to questions listed below the photo that students were expected to respond to in her blog comments section. The questions were: "What are you thoughts as we begin the lesson on building and coding web pages? Are you confused? Excited? Nervous? How can this blog and online community help you to become a better web designer?" Students immediately were engaged with replying to Ms. Mendoza's questions, and several students even started marking that they "liked" her posting on the blog page. When Ms. Mendoza realized students were "liking" her blog post online, she exclaimed "Did you 'like' my post?! That's right! You better, 'cause my pic is up in there!" This got the entire class laughing together. Lena moved next to Samson, asking for his help finding the "comment" box on Ms. Mendoza's blog as students continued to post their comments on the webpage. (M.FN.1.13.12)

In this classroom, the comfortable humor shared between students and Ms. Mendoza seamlessly spread to students' peer-to-peer practices. Ms. Mendoza regularly began her class with handshakes at the door. Whenever students (like Andrea in the vignette above) appeared to be in a poor mood, Ms. Mendoza used her sense of humor to energize them again. This playfulness continued into the daily sharing of "good news," as visible in the above excerpt where students' comments were treated with zeal. In this particular instance, students encouraged Ms. Mendoza to participate rather than only ask students to share. She quickly described her excitement about spending time with the Senior class, reflecting how she was building positive relationships with the Senior community. Ms. Mendoza's "good news" encouraged Juliette to share next. Her news took the form of a joke, pointing out her excitement about the upcoming three-day weekend. Students were quick to applaud Juliette's announcement, reflecting how willingly they joked about avoiding school, while also appreciating each other's participation. Even Andrea built off of Juliette's three-day-weekend joke by mentioning her happiness that it was Friday. Showing a welcoming attitude to student humor, Ms. Mendoza had the entire class celebrate that it was Friday rather than just brush over Andrea's announcement.

The sense of community Ms. Mendoza built through humor was also visible when addressing a disengaged Irene. While teachers often sound condescending or sarcastic when asking a student not to "fall asleep," Ms. Mendoza's playful response to Irene putting her head

down did not feel aggressive or mean as reflected in her classmates' smiles toward Irene following Ms. Mendoza's comment. Peoples' reactions were supportive rather than negative. Ms. Mendoza's subsequent sense of humor when disciplining Shari and Xochitl for arriving late to class was also met with a positive response from students. Without any animosity, anger, or apathy—all of which are potential reactions to discipline—Samson picked up on Ms. Mendoza's sense of humor by pointing out that it was "1:40 somewhere in the world" in defense of Shari and Xochitl. Even Xochitl was able to joke back when Ms. Mendoza speculated that constipation was slowing the girls down, reflecting a sense of comfort and openness in the classroom community.

Humor continued to bring students together when Ms. Mendoza instructed Lena to check out the "sharklasers.com" website. Not only did this website make Lena laugh, but it also encouraged other students to find out why Lena was laughing. The subsequent gathering of students around a single computer created a moment of community and friendship which, while not necessarily related to the computer science learning at hand, inspired connection between students. That feeling of connection spread as Nico's peers congratulated him on running a marathon. Instead of disciplining students for talking about unrelated topics, Ms. Mendoza joined this conversation, encouraging Nico's athletic efforts.

This feeling of community translated into the ways students shared their blog addresses with one another. The funny blog names that students created reflected humor's value in the classroom; students made an effort to make each other laugh just like their teacher. Ms. Mendoza positively reinforced this humor by laughing at students' blog names as they proudly identified themselves for recognition. Ms. Mendoza kept students laughing by choosing the "XXX69" blog

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when demonstrating blog subscriptions. The laughter shared between students and teacher created a lively feeling in the community.

Ms. Mendoza's playfulness was contagious. Students at Irene's table proceeded to make each other laugh while remaining engaged with the activity at hand. Building off Ms. Mendoza's sense of humor, Larry and Albert pretended that no music was playing when Irene heard it coming from Larry's phone. As students at the table laughed together about Irene's Katy Perry jokes, she proceeded to call Albert a "troll," humorously commenting on his blog name. Students used humor as their means of communicating, but were still engaged with their blogs as visible when Samson easily shifted the conversation topic to changing his blog page color, and as Albert willingly paused his funny conversation to help Samson. The fact that students would not only be able to joke with each other, but also turn to each other for assistance reflects the sense of trust and community in this computer science classroom.

Of course, the humor did not stop here. Ms. Mendoza infused the next journal activity with laughter, using her own picture to emphasize the journal questions while acting proud of her blog. The constant use of humor in the classroom—starting with Ms. Mendoza's interactions with students that spread to interactions between students—revealed how humor was valued in this classroom and also facilitated positive conversation between students.

While Mr. Torres's use of humor was very different at Presidential High, his willingness to joke also created a sense of community in the classroom, visible in the ways students participated in whole-group discussions. Building upon the quality of Mr. Torres's playful tone, students opened up to one another and made efforts to joke as demonstrated in the excerpt below:

While projecting his own computer screen on the front board, Mr. Torres began directing students on how to build a word cloud with their snacking data in JGR/Deducer. He told them to go click on "text" and "view frequency," but before he could say the next directive, Isaac offered the next step, "word cloud?" and Mr. Torres smiled in agreement. Suddenly, Mr. Torres

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dramatically announced, "I'm hungry! So I'm going to eat my *apple*! See, I walk the talk!" (Referring to how he was eating healthy snacks, the topic of the students' mobile phone-based research). Before Mr. Torres could bite into his apple, Emilio called out, "Can I have it?" Mr. Torres looked surprised, then said he only had *one* apple, to which Belén smiled and pointed out that Mr. Torres could cut it in half to share it. Recognizing the joke, Mr. Torres smiled and said he would just wait until later to eat his apple. Belén and Emilio laughed. Then, Mr. Torres continued teaching students about how to build the word cloud, instructing them on how to add color to their data representation.

As the word clouds popped up on students' computers, Marisa called out "This is cool!" and Mr. Torres smiled while replying, "It's cool, right?" Then he asked the class, "What are the large words?" Students read off "ate" and "milk" and Mr. Torres replied, "looks like a lot of you seem to like milk! What else stands out?" Manuel said, "The unhealthy things, you can really see it…" and Isaac commented, "let's try purple and green!" (because the word cloud Mr. Torres had students create displayed all words in shades of yellow that were difficult to see against a white background). Mr. Torres, agreeing with Isaac's suggestion, changed the color of his own word cloud as students gave different suggestions for other color combinations. Then Mr. Torres asked students to describe what other words were prominent in the cloud. Students noticed "cereal," "banana," "apple," "peach," and "rice." Mr. Torres noticed "*pupusa*" was also in the word cloud and asked students what ingredients were used for making *pupusas*. Students called out that there was cheese and sometimes *chicharonnes*, suggesting it was an unhealthy snack. But then Manuel countered, "But they put salad on top too! So it's like half healthy!" Mr. Torres laughed and asked if the salad balanced it out and Manuel said that it did. Then Marisa pointed out that the tortilla part was unhealthy but Alberto and Manuel retorted that *masa* was used for making *pupusas* that wasn't as bad tortillas.

Mr. Torres moved on and asked about specific words in the word cloud: "Is the top right supposed to be popsicle?" Someone had misspelled it as "posicle" and Marisa joked, "maybe it's *supposed* to be posicle!" and they laughed together. Mr. Torres asked students what a "*bolis*" was and students explained that it was like frozen Kool-aid. Mr. Torres then asked what ingredients were included in a "*bolis*," and students said a lot of sugar was used. Then Tomas (who was usually silent in class) pointed out, "There's fried Kool-aid too! Ever heard of it?" Mr. Torres said he hadn't heard of fried Kool-aid and Tomas explained that he saw it at the --- County Fair and that there was even a *Youtube* video online that explains you how can make it. Mr. Torres, encouraging Tomas's participation, said he would have to check it out.

Then Mr. Torres noted, "I thought Cheeto's would be bigger on the word cloud. Isn't Cheeto's your favorite snack?" Manuel quipped back, "That's *middle* school food!" and Mr. Torres retorted, "Even though Marisa was eating it earlier?" Marisa mentioned that the older version of Cheeto's that came in cups was better. Mr. Torres asked if this was true, and as she nodded her head, Jesus started using the shadow of his finger in the projector light to point out other words in the cloud on the board. Mr. Torres smiled back at Jesus, saying, "Okay, we get the point. Thank you." Everybody started smiling together. (P.FN.5.4.12)

The sense of community built through humor was visible in Mr. Torres's willingness to

joke with students and their desire to joke back. Such playful banter helped build a space for

communicating ideas about food consumed during the snack study. From the beginning of the

excerpt, Mr. Torres showed his sense of humor by acting self-righteous about his apple snack that students quickly teased him about sharing. Mr. Torres's willingness to joke and be playful created space in his classroom community for a subsequently lively conversation about data in the word cloud. Manuel made the light-hearted comment about how the cabbage-based salad eaten on top of *pupusas* made them healthier than they would normally be. Mr. Torres encouraged Manuel's participation by laughing with him about this idea, which seemed to motivate others to share about what they knew regarding *pupusas*, namely, that tortillas were unhealthy but that the *pupusas* were made with *masa* that was healthier. Humor around *pupusa* salads being healthy created a space in which other discussion could be had about how to define "healthiness" in a snack.

This openness toward humor encouraged Marisa to joke with Mr. Torres about the potentially purposeful spelling of "posicle" over "popsicle." Being able to laugh over something as simple as the spelling of "posicle" appeared to relax the class atmosphere as students then proceeded to share their personal knowledge about "*bolis*" and "fried Kool-aid." Students' feeling of comfort and willingness to share with the community discussion seemed particularly clear for Tomas who was very shy and never offered answers but decided to share what he learned about fried Kool-aid at the local county fair.

The ways that a classroom community feeling was bolstered by humor also became apparent as Mr. Torres proceeded to joke that he thought there would be more Cheeto's in the data collected. Manuel quickly joked back that Cheeto's was a "middle school" type of food and Marisa explained that Cheeto's from the past that were served in cups tasted better than current Cheeto's in a bag. The tone of the conversation mimicked one that might take place with friends rather than in a classroom, reflecting how humor allowed students to become comfortable with

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sharing their perspectives in a playful way. Then, Jesus's approach to highlighting data in the word cloud using his finger's shadow in the projector light further emphasized how Mr. Torres welcomed playful humor as a means to engage classroom community. By responding to Jesus by saying "We get the point" and thanking him, Mr. Torres emphasized his recognition of Jesus (rather than disciplining him), while soliciting a shared laugh from the rest of the class.

Overall, students and teachers agreed that humor could be an important tool for building a sense of community in the classroom. Teacher-to-student and student-to-student relationships were facilitated through playful joking and laughter.

Discipline

Students at all three dissertation schools were clear about their dislike of boring teachers *as well as* their dislike of angry teachers who disciplined by yelling. Students believed that teachers who had a sense of humor appeared kinder toward student mistakes which, in turn, helped students relax in the classroom and willingly participate in learning activities.

Mr. Santos of City High echoed this sentiment when explaining how humor helped him address disciplinary issues while motivating students to learn. In disciplinary situations, Mr. Santos believed that joking helped students recognize that their negative behaviors were unwelcome without suggesting that *they* were unwelcome:

> I'm not punishing the kid, I'm punishing the behavior…I let them know and then I turn around and move on or ask them a joke…let 'em know that it's not personal, I don't have anything against the kid…we have some laughs after about something or other, and it kind of washes things down. (C.T.Int1.12.15.11)

Emphasizing how humor helps students feel that *they* aren't being criticized as human beings, but instead their *actions* are being pointed to, Mr. Santos illustrated how joking can help students reflect on their behaviors without feeling condemned. As a result of this approach, Mr. Santos

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noted: "I see more work. I see better work too. I see more quality work…because they don't want to let me down" (C.T.Int1.12.15.11).

For Mr. Santos's student James, humor was essential to avoiding disciplinary situations by changing the atmosphere of the class. James explained that Mr. Santos knew how to use humor to avoid disciplinary situations:

> His humor I guess, he has a specific way…he kinda works the mood of the room…to focus all the attention on the board and him. So you don't really even realize it until you actually find out, "Oh wow, look at what I'm learning!"...He hasn't kicked a single student out of his room even though they don't pay attention. Because he naturally gets attention over time. (James, C.Int3a.5.14.12)

James emphasized how Mr. Santos knew how to shift students' attention toward the teacher and computer science by incorporating humor into the classroom. As the classroom mood changed, so too did student engagement with new ideas.

Interestingly, all three teachers used humor when disciplining students, pointing to unwanted behaviors in ways that made students smile without aggravating the situation. Mr. Torres at Presidential High used humor to take the negative edge off his position of authority and build a friendly rapport with his students that could motivate compliance with—instead of resistance to—classroom rules. For example, when Brittany was caught texting on her mobile phone, Mr. Torres said dramatically, "Brittany! Do you value your phone and personal electronics? Because I need some new inventory for my eBay account. It would be good if I could earn some money for some Christmas spending!" (P.FN2.8.17.11). Brittany smiled and responded positively to Mr. Torres's comment, immediately putting her phone away and keeping it in her bag for the rest of the class. Mr. Torres's comment about selling student phones on eBay also solicited several laughs from students while reminding them about his class rules.

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In a similar situation at Midtown High, Ms. Mendoza noticed a student texting, stopped herself in the middle of her instructions, held out her open palm to the student, and said with a smile: "I love you, but…" while motioning for the student to give her the phone. Without looking upset and while recognizing her mistake, the student handed over the phone. Ms. Mendoza immediately laughed and called out, "I'm ballin'!", suggesting that she had acquired expensive equipment. Students laughed with her, calling out that she could probably sell that phone for a lot of money online. The student who had made the mistake of texting during class simply smiled, showing no signs of anger at Ms. Mendoza's humorous disciplinary action. (M.FN.10.7.11).

On a different occasion at Presidential High, Brittany was chatting loudly with a classmate, interrupting Mr. Torres as he was speaking. Mr. Torres turned to the two students and asked, "So are we going to have to put you guys in the relocation program? The witness protection program? Send you away for a little while?" The two students replied with smiles and said "no" as Mr. Torres replied, "Okay, well then let's stop the side conversation." During the rest of class, Brittany did not chat again (P.FN.8.26.11).

Using a more advanced technological tool at his disposal, Mr. Torres would also use humor to discipline students who were using their computers for off-task activities (e.g., reading manga online, shopping online, playing computer games, etc.). Mr. Torres had installed a software program that allowed him to see every student's computer screen on his own desktop. In this way, he could check if a student was off-task and could manually close their internet browser or game window from his own computer. Then, he would post a humorous image on that student's screen that said "Big Brother is watching you." During the seventh day of class, right after Mr. Torres assigned the day's activity, Marisa noticed her computer screen taken over

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by the "Big Brother is watching you" window when she had been playing a game online. She looked surprised and laughed, asking aloud, "Is this Mr. Torres?!" Mr. Torres smiled and replied to the entire class that students should be careful and get started on their assignments because he was checking on them. Instead of becoming annoyed or defiant, this funny way of managing students' computer-use proved a positive means of keeping students engaged with their assignment for the day (P.FN8.31.11).

During the ninth day of class, Mr. Torres also used humor to motivate students to get to their assignments while disciplining them about off-task internet searching. At the beginning of class, Mr. Torres had asked students to come up with definitions for several vocabulary words as their morning journal entry. A set of four girls who always sat together were looking at news articles about Kim Kardashian online instead. Mr. Torres quietly walked over and read over their shoulders, then said loudly, "Okay! Let's leave Kim Kardashian alone and get to the vocab. Kim makes enough money! Don't give her more money by paying attention to her online! She makes four million a year, and then you buy her clothes and give her more…I don't know! It's up to you!" and he walked away. The girls burst out laughing, and one of them said "Okay, okay…" as they proceeded to start the vocabulary assignment. If Mr. Torres had disciplined the girls harshly by asking, "What are you doing?" or "Stop looking at Kim Kardashian and start working on the vocabulary!" the girls would most likely *not* have responded with smiles or laughter and may have been less willing to get to their assignment. But instead, Mr. Torres's humorous mini-lecture about keeping Kim Kardashian rich made the girls laugh so that their transitions into school work seemed a little easier to handle. (P.FN.9.14.11)

During that same class meeting, Belén started swearing loudly in the middle of class. Instead of simply reprimanding her, Mr. Torres said, "Ladies! Language! Unless you're going to

truck driver school, please be careful about the language you use in the classroom!" This made Belén and several other students laugh. As Belén conceded to Mr. Torres's request, adding her own creative humor to the situation by saying, "Okay! What the fudge…what the farm…" If Mr. Torres had simply yelled at Belén to stop cussing, she may have continued cussing under her breath or refused to respond. Instead, since Mr. Torres made a joke out of her poor language, Belén was able to smile while simultaneously recognizing her mistake, turning her profanity into creativity (P.FN.9.14.11).

At Midtown High, Ms. Mendoza regularly used humor to alert students of negative behaviors and encourage positive ones. During the second week of class, Ms. Mendoza used humor to critique students' poor treatment of the laptops and to demonstrate how students *should* be putting the laptops away in the cart. Ms. Mendoza's humorous methods for classroom management are revealed below:

> As Ms. Mendoza began describing the day's agenda, she moved over to the laptop cart and stated, "Another thing…last time you used the laptops—and you *were* the last to use the laptops—afterwards I looked through them and was *appalled*!" Ms. Mendoza jokingly said, "Okay, so next time you are putting the laptops away, let's use *these* things we call *knees*…" and she pointed to her knees and slowly bent them so that she could see into the laptop cart. Students started to laugh as Ms. Mendoza continued, "Let's use our *knees* so we can see the numbers [labels] and put the laptops on the correct shelves. Now you will notice, each row has a charger. They might be hidden, so once again, let's use these things called *knees* and reach back and find the cords. You shouldn't have to connect one from a different shelf to a lower shelf. Sometimes they just get hidden and you have to find them and plug the laptops in…" The students listened attentively and then Ms. Mendoza added dramatically: "I was really disappointed…But you are forgiven!" And then she gave a sign of the cross over the class and whispered in Spanish: "Father, Son, Holy Spirit," mimicking the way a Catholic priest would bless and forgive sinners during a confession. The whole class burst out in laughter and, later, proceeded to put more effort into putting the laptops away. (M.FN.9.27.11)

The use of humor with Ms. Mendoza's dramatic gestures effectively caught her students' attention and directed them to what she believed to be important and proper behavior in her classroom.

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On other occasions, Ms. Mendoza's combination of discipline and humor proved effective in generating positive student action. For example, when walking around the classroom, if Ms. Mendoza noticed a student had his head down or her backpack still on, she would poke them jokingly in the ribs with a laugh while walking by (M.FN.9.27.11) or help them physically take off their backpacks while saying "Get comfortable! Take off your shoes!" (M.FN.10.11.11). During another instance, when Xochitl and Dario were chatting instead of writing their journal responses, Ms. Mendoza sauntered past saying, "You're being as useful as a screen door on a submarine!" Xochitl asked in response, "What's a submarine?" And without being critical of Xochitl's lack of English vocabulary knowledge, Ms. Mendoza quickly replied, "Well, 'sub' means 'under' and 'marine' means 'water." So they're ships underwater." Xochitl still didn't understand Ms. Mendoza's joke and so Ms. Mendoza explained how, when you're underwater, a screen door isn't useful because the water can come through the door. Since Xochitl still looked confused, Ms. Mendoza gave another humorous analogy: "You're being as useful as a pair of gloves on Captain Hook!" and then she laughed while making a hook shape with one hand, showing how you can't wear a glove on a hook. Xochitl, Dino, and students nearby proceeded to laugh with Ms. Mendoza as the two off-task students began working on their journal entry (M.FN4.20.12). The use of humor in these situations brought attention to correcting the behaviors of students rather than focusing negative attention on the students themselves. Furthermore, students were able to laugh with the teacher about these disciplinary situations instead of responding in ways that challenged the teacher.

Yet did these humorous disciplinary interactions actually affect classroom behaviors over time? Interestingly, instances of student distraction and disengagement (e.g., chatting with peers about topics unrelated to material being learned, playing computer games, checking mobile

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phones, etc.) and teacher discipline (e.g., calling on students when they are distracted in order to regain their attention, challenging undesired behaviors, etc.) decreased in all three classrooms from Fall to Spring semesters. This was especially true at Presidential High. During the Fall semester, as Mr. Torres was establishing his classroom community, Presidential High experienced an average of 10.42 student distractions and 9.33 disciplinary actions per class. Yet, by the end of the school year, during the MyData Unit, there were only 2.375 student distractions and 2 disciplinary actions on average per class. Similarly, at Midtown High, Ms. Mendoza decreased her disciplinary actions from an average of 6 per class at the start of the school year to only 2 per class during the end of the school year with student distractions and disengagement decreasing from an average of 3.4 to 1.64 instances per class. While the decrease in student distractions and teacher disciplinary actions at City High was not as great, neither distractions nor disciplinary actions were as common at this school. Still, there was a clear decrease in both as the year progressed. Student disengagement and distraction decreased from 3.48 to 2.77 instances per class from Fall to Spring, with teacher disciplinary actions decreasing from 1.84 to 1.5 per class as well. These shifts in behavior are visible in the tables below:

Figure 7.3: *Average Number of Instances of Student Disengagement/Distractions Per Class*

SCHOOL	Beginning of the School Year (Fall Semester)	End of the School Year (MyData Unit)
Presidential High	10.42	2.88
Midtown High	3.4	1.64
City High	3.48	1.59

Figure 7.4: *Average Number of Instances of Teacher Disciplinary Action Per Class*

SCHOOL	Beginning of the School Year (Fall Semester)	End of the School Year (MyData Unit)
Presidential High	9.33	2
Midtown High	6	2
City High	1.84	1.5

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These shifts in student disengagement/distraction and teacher disciplinary action indicate that something important must have changed in the three classrooms' community dynamics from Fall to Spring. While it is possible that the differences in student disengagement/distraction and teacher disciplinary action may reflect changes in student enrollment (as some students left the class after Fall semester and new students joined for Spring semester) or greater student interest in material being learned in the Spring MyData Unit, student interviews and classroom observations suggest that teacher humor played an important role in this change.

For example, several students noted that their teachers' abilities to use humor to make learning fun were key in getting them more involved in learning, decreasing the potential to become disengaged or distracted. While this idea was already explored in the "Motivation" section above, let us consider the reflections of two Presidential High students who struggled the most in Mr. Torres's class. Emilio was a student who had difficulty with various assignments in Mr. Torres's Discovering Computer Science class throughout the school year. However, he was rarely absent and told me that he enjoyed coming to class, noting, " 'cause if I have fun in that class, then I will do the work…'Cause some other teachers just stay there and they be mad of you, if you don't do your job. But this teacher'll be like, 'Yeah Man! Do this! You have a life! You gotta be something in life!'" (Emilio, P.Int14.5.7.12). In this interview, Emilio emphasized how Mr. Torres's sense of humor motivated him to study and contrasted greatly with the negative teachers who didn't have fun and, instead, showed anger or frustration with struggling students. It was illuminating how Emilio noted that teachers who were always "mad" and disciplining him had the opposite effect of Mr. Torres's sense of humor that made learning "fun"

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and helped Emilio believe that he could "be something in life." Emilio linked this humor-driven, positive attitude with his belief in the potential to succeed.

Similarly, Daria contrasted Mr. Torres to other teachers who were not as "nice.". During the Fall semester, Daria was often absent and, when present, preferred putting on makeup instead of working on computer science assignments. During our interview, Daria was honest about the fact that she didn't always pay attention in Discovering Computer Science but that her appreciation of the class grew over time. By Spring semester, Daria was rarely absent. Daria revealed that this shift in behavior was a result of Mr. Torres's funny attitude. She explained, "I don't want a grumpy teacher always screaming at us and everything, I don't really like that. I don't pay attention, or talk to other friends and don't really care. But he really cheers [me] up and makes me want to work" (Daria, P.Int15.5.8.12). Teachers who use humor as a pedagogical tool can be transformative for students like Daria who are accustomed to teachers yelling at them when they are off-task. Opposed to discipline through yelling or harsh words, when laughter is used as the tool to manage the classroom while also engaging students with a positive attitude, the motivation to learn increases.

Mr. Torres explained that the reason why humor-based discipline worked was because it was rooted in "caring." He noted that "checking" a student who misbehaves was his way of "show[ing] these students that I care" (P.T.Int2.5.29.12). This may illuminate why students did not feel put-off by these three teachers' disciplinary actions and why instances of disengagement and distraction decreased over the school year. When humor was used to point to student behaviors in a caring way, students were open to changing such behaviors.

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Conclusion

Indeed, the *intentions* of humorous comments and actions in the classroom as well as teachers' *delivery* of such comments/actions were key to humor's effectiveness in motivating student learning, countering stress, building community, and disciplining undesired behaviors. While teachers' jokes and joking styles were often spontaneous and played off of what was being said or done in the moment, neither jokes nor joking styles were haphazard or malicious. The ways teachers exhibited humor were rooted in the intention of supporting students in the learning community and colored by a feeling of respect for students. Teachers also showed humbleness in their abilities to laugh at themselves. These teachers never used humor that was meant to insult or offend and never used humor in a passive aggressive way to mask anger or annoyance. Even when disciplining students, humor was used in a thoughtful manner to encourage positive participation and teachers did not exhibit frustration through their humor-based discipline.

Intention and delivery are important to keep in mind when considering how to apply humor as a pedagogical tool in classrooms. This pedagogical approach will not work for those who do not laugh easily or enjoy laughing. This pedagogical approach will also fail among teachers who want to keep a wall separating themselves and their students in a hierarchically organized classroom space. This is because teachers' uses of humor as demonstrated in these dissertation classrooms involved a process of becoming friendly with students, engaging with them in ways that blurred the traditional lines between teacher and student. Teachers needed to trust that students would understand their humor while also being humble enough to accept that students might push and joke back. As a result, teachers needed to be open to student humor and potentially becoming the focus of laughter as well. Teachers also needed to be skilled at redirecting laughter back to the lesson at hand.

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Teachers who wish to engage a productive use of humor in their classrooms must be open to that liminal space created by laughter. Similar to the ways a class clown uses humor to remind us "just how boring school really [is]" in ways that simultaneously illuminate the "tenuousness and arbitrariness of the codes" or rules of the classroom (McLaren, 1993, 161), teacher uses of humor can create an environment charged with an energy of that space in between play (rarely equated with computer science learning) and seriousness (which many tend to believe learning should be). There is an electricity to that feeling between playfulness and seriousness when humor is injected into a classroom, and it is in that liminal space that teachers may find a potential to enrich students' learning experiences (as described through the three dissertation teachers' examples in this chapter). However, a teacher may also lose her or his learning direction completely when balancing in that liminal space. For those teachers who do not know how to direct humor toward supporting learning in the classroom and who might get lost in the liminality of classroom humor (e.g., losing students' respect for the sake of a joke, disrespecting students and taking a joke too far, losing sight of the purpose of the day's lesson as a joke continues, etc.), this pedagogical tool may weaken rather than strengthen the learning community.

Yet, as with any pedagogical method, humor is a tool that teachers can perfect and make their own with attention and practice. The ways Ms. Mendoza, Mr. Torres, and Mr. Santos employed humor to build caring classroom communities and break students' psychological barriers to learning computer science were inspirational. However their humorous teaching styles did not simply appear overnight as both Ms. Mendoza and Mr. Santos described their processes of finding their current teacher personalities and relaxing into the funny teacher roles they play today.

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Furthermore, a funny teacher does not magically make quality learning happen. However, when humor is used in conjunction with connected computer science pedagogy or any of the other teaching practices described earlier in this dissertation, a teacher may be opening new lines of entrée to diverse students who never considered learning computer science before. The playfulness and creativity of humor may provide students with new perspective and motivation to enter a field that may have felt previously inaccessible.

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"WOW! Now when I research, I ask myself questions, I am more analytical":
Student Learning with MyData

> "[T]he [MyData] Unit, I think it was very cool. I think that [it's one of] the two
> things I'm going to remember most about this class…I've always been someone
> that has felt that education needs to be advancing just like how we are advancing
> in all the other ways of our life…We shouldn't be scared to try new ways of
> learning. And if it doesn't work we'll try again. But I like those kind of innovative
> things where people are learning in a different way. I just want to say that
> America shouldn't be 23rd in the world in education. We should be number 1. I
> think with things like this we can get there." (Darrell, C.Int2.5.30.12)

Students highly enjoyed the opportunity to conduct community research using mobile phones. Of the forty-one students interviewed specifically about the MyData Unit, forty students emphatically expressed that they both liked the mobile phone project and would do more community research if given the opportunity. Many, like Darrell above, appreciated the innovative nature of this unit and its activities because using mobile phones for academic and community research purposes was something completely new. Valuing the sense of responsibility conferred upon them when borrowing brand new smart phones—as Annie explained, "the fact that they were trusting you with the phone…it gives you this *feeling*!" (Annie, M.Int10.6.1.12)—students especially enjoyed working with their own data: "It felt pretty cool…'Cause I felt like I did something with *my* data" (Enrique, M.Int11.6.11.12).

While it is important for students to "enjoy" educational activities in order to increase motivation and persistence to learn, teachers had bigger goals in mind for their students when conducting mobile phone community research.

Teachers' Unit Objectives: Understanding the Power of Data Beyond the Classroom

Ms. Mendoza, Mr. Santos, and Mr. Torres shared similar learning objectives when teaching the MyData Unit. All three teachers wanted students to understand the power of research and potential social impact of collecting and analyzing data.

On one level, teachers wanted students to understand that they could pursue research as an occupation. Mr. Santos mentioned that he wanted students to see how data analysis did not end with "just this project [because] there's a whole field of work and of knowledge behind this little concept…somebody's going to be paid for doing this, so why not you?" (C.T.Int2.6.4.12). On another level, teachers hoped that studying snacking habits would open students' perspectives regarding how data can improve your daily life. Mr. Torres explained, "I wanted [students] to understand the power of data, and how data can affect change and…It behooves you to eat healthy…that they'll hopefully start changing the way they view food, the way they view the things that are readily available in this community, and maybe venture out to other areas" (P.T.Int2.5.29.12). And on yet another level, teachers hoped students would see that data can both help or harm their local communities. Ms. Mendoza shared that she wanted students to understand "The importance of using data…the science behind it all…how data can be used to manipulate something….Because that's how [data are] used against people of color! You know? We talk about Black people or this and that, and *we* say: 'No, it's not true!' And *they* go: 'Well look at the data'" (M.T.Int2.6.14.12). To counter such external manipulation, Ms. Mendoza added that students should be empowered to share their own stories for social change and not be limited by peoples' decisions made outside their communities. Using the Jamie Oliver *Food Revolution* TV-series as an example, she explained:

> [T]o really see the flip side of what Jamie Oliver was trying to do, and having a
> conversation about [how] this is an Englishman…he's coming into a low-income

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community…he's trying to show that these people, these kids who have high rates of obesity… don't know where their food comes from and they're stupid…it becomes this same story of the White man trying to tell these kids of color what's right and "I'm gonna save you!"…[T]hat really helped [my students] to see why we need to explore it for ourselves. Why that's really important that *we* do the research. (M.T.Int2.6.14.12)

To these ends, all three teachers emphasized the importance of understanding the role of data and research in society today.

Yet what did students learn?

Student Testimonies About Learning

New Understandings About Data

"I didn't even know it was data!" (Veronica, P.Int1.5.16.12)

The majority of students did not realize that data included information beyond the tables and graphs they had experienced in math or science classes. As Darrell from City High noted, "my sense of data now encompasses my entire surroundings, it's not so much just what I see in a computer table…You don't realize it, until I was actually out there taking pictures" (Darrell, C.Int2.5.30.12). James echoed this thought, explaining:

> My definition of data is completely blown out of the water…When I thought of data, before this whole [MyData] project, I thought numbers. That's all I thought…That it could be something as simple as a survey and a picture, you know? I was like, "What? This is data? This is just me answering questions and taking a picture of what I asked the questions on!" What do you know? That's data! (James, C.Int3a.5.14.12)

Most students, like Juliette at Midtown High, "never really thought about the word 'data,' or 'collecting data' [before]" (Juliette, M.Int3.6.8.12). Previous to the MyData project, many had incorrect definitions for data: "I thought like it was just a USB thingie" (Marisa, P.Int5b.5.4.12). Following completion of the MyData project, students shifted from thinking data are "little research…little words" (Veronica, P.Int1.5.16.12), "just charts" (Guillermo, C.Int9.6.1.12), "simple numbers" (Ricardo, C.Int8b.5.24.12), or "some type of word for technology" (Reina,

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P.Int8.5.25.12) to understanding data are "everywhere" (Reina, P.Int8.5.25.12) or "mostly everything" (Veronica, P.Int1.5.16.12).

Students emphasized new definitions of data as "useful": "now I know more about how to *use* the data…to either improve or just to see what we're doing" (Isaac, P.Int4b.5.16.12) and "[I'm] more aware of how data is used" (Lisa, C.Int4.5.17.12).

As students gained new understandings of data, their interest in data increased. Enrique moved from seeing data as "some random points and plots on the graph" to something "interesting" that could lead to "different solutions to this specific topic and stuff" (Enrique, M.Int11.6.11.12). Alberto of Presidential High described wanting to learn more about data "because if you collect data you could see a lot of different things with it and use it in different ways" (Alberto, P.Int3.5.8.12). Jesus described an increased interest in data "Because [the project] showed me how data works more than I used to" (Jesus, P.Int11.5.11.12). Alejandra of City High told me she now enjoyed working with data as a result of her MyData project: "I had totally changed my point of view and I actually see what is going on in our world. In our society" (Alejandra, C.Int10.5.23.12). These testimonies revealed that students' interest in learning about data increased when recognizing its value in society. With great enthusiasm, Carlos described that data "actually helps us to solve that question and to understand it. And then that's like one less question to understand in the world!" (Carlos, C.Int1.5.9.12).

Learning about Research – Being "part of the opinion that counts!"

> "The most important thing that I learned doing the project was how we use data after we collect it; how we look through it" (Isaac, P.Int4b.5.16.12)

Coupled with students' excitement about understanding data was their growing engagement with new perceptions about research. James explained:

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'Cause you ask someone about data, and they're like, 'Oh, yeah, it's peoples' opinions or anything that has anything in relation to an object that you're trying to figure out more about.' Well, okay, how do you *get* that information?...I wondered how they actually got that. But then, I had a chance to actually be part of the opinion that counts! It's actually cool how you collect data! (James, C.Int3a.5.14.12)

This idea that students could be "part of the opinion that counts" was both new and compelling to most students participating in this project. Numerous students emphasized that they were surprised about the sense of empowerment they experienced by conducting research. Lisa described the importance of "get[ting] to make your own conclusion [because it] helps you give yourself a voice and opinion that matters" (Lisa, C.Int4.5.17.12). Lisa reflected a more nuanced way of thinking about the research process: "I always had to do research projects but I never had to do it where *I'm* collecting the research *myself*…[that's important because] with somebody else's information you're not quite sure exactly what their standpoint is" (Lisa, C.Int4.5.17.12).

Darrell also appreciated the feeling of self-efficacy garnered by conducting his own research through the MyData Unit:

I have a lot of power through science! Through the scientific method, there's a lot of things that I can do. I can be someone [who] actively surveys our world, someone that really can be concerned about issues…I don't need to rely on CNN to come out and report something. If I see something I can go out there and I can record that information or get that data. (Darrell, C.Int2.5.30.12)

These new feelings of independence and students' developing identities as community researchers were echoed by numerous other students. Samson at Midtown High expressed surprise when realizing that he could have an impact on his community through his own research:

I didn't think that being unhealthy would be a research that could be taken care of. Or that something small like that could be such a big thing in our community…now, if I ever want to research something, I could be like, "Yeah, I know how." Or like, "I know what to do." (Samson, M.Int4.6.1.12)

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Samson's classmate Juliette didn't know it was possible to conduct research using a mobile phone and felt empowered by this new research approach to an everyday tool: "I could come up with a conclusion any time I feel like it or any time I have a phone with me!" (Juliette, M.Int3.6.8.12).

Students' growing notions that they could be researchers proved to be motivational and inspiring for many students. As Israel explained, "It made me feel more into the project, into the subject. [I] felt like reading more about it and searching it up more" (Israel, C.Int16.6.4.12). Orlando echoed this sentiment: "it's [the research is] getting me into it because I wanna know!" (Orlando, C.Int18.5.7.12). Or as Hyun explained,

> [I]t's fun and interesting…I learn more about stuff if I do it this way since I gather a lot of information through the phone…I think it's better to go out and discover stuff with the [MyData] data instead of trying to look online on the computer… I enjoyed it because it was something I didn't do before. Something that I never tried and I never thought I would until I discovered it through this class. And it changed the way I look at research now. Maybe whenever I do research, I would try to go outside and communicate with the world. Try to gather data instead of looking online now. (Hyun, C.Int14b.5.24.12)

This desire to "try to gather data instead of looking online" was echoed by many—including Natalia, Jesenia, Adrian, and Nico from Midtown High—who all ended their interviews ecstatically noting that they wanted to do more research in the future.

While empowering and motivational, learning how to do community research using mobile phones also gave students ideas about how to be creators of new ideas with technology (instead of mere consumers of technological tools), demystifying the research process. A range of students pointed out that they had never collected their own data before and *especially* never with a mobile phone. For example, Manuel (a 10th grader who never passed his Algebra I class) exclaimed, "I never thought about using the phone to help you do classwork" (Manuel,

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P.Int13.5.9.12), while Darrell (a senior who went on to attend Harvard University after graduating from City High) noted:

> My idea of research was really refined in my AP Psychology class where I actually did a real research paper for the first time…But I think my idea of research has become more enhanced in this class because I realized that I could go out there and just do it with a cell phone camera…I don't have to be in some laboratory doing research, it could be right here on our streets! (Darrell, C.Int2.5.30.12)

The novelty of conducting research with mobile phones was felt across all high schools, with students sharing, "Yeah, that was new!" (Ruby, C.Int6b.5.22.12), or "it helps you find out things that you never thought of" (Malia, C.Int7.5.11.12), or "I didn't have an idea that we could do that…it's a really cool idea" (Gustavo, C.Int12.5.30.12), or "I actually paid more attention" (Julieta, P.Int10.5.11.12) or "I never even know that we can do that on the phone!...It was absolutely new!" (Anthony, M.Int5.6.1.12).

It is important to note, however, that students' excitement moved beyond the technological tool and was driven more by their new abilities to do their own research. Data collection and analysis became demystified:

> Oh, no no no no no no! I never thought that I could actually do that [research and data analysis] by myself. I always thought that there's somebody doing it for you and for everybody else…[I]t's cool to know that you can do your own data and even if you don't have the phone, you could still do it by yourself. Just, you know, doing it on a piece of paper. (Annie, M.Int10.6.1.12)

Similarly, Veronica noted, "I didn't even think that this was research until Mr. Torres….made us do that data thing…and I thought that was really fun" (Veronica, P.Int1.5.16.12). Alejandra of City High also showed her enthusiasm about doing research:

> It's awesome! I actually like doing it. I didn't know it was that fun. Because, to me, about data and work, just, with those words, it's like, "Oh I don't feel like doing it." But when you're actually working on it, you learn new things and you know that you can use it in the future. And that's awesome. (Alejandra, C.Int10.5.23.12)

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Conducting research was no longer intimidating as Belén of Presidential High pointed out, "At first I didn't know what was data and how to use the computer…but now it's easy!" (Belén, P.Int6.5.9.12).

Students clearly met teachers' stated goals, making important gains in their understandings of data and the power of research. Yet how did students make this leap into recognizing their abilities to conduct research? James from City High reflected on this during his interview, emphasizing the importance of physically exploring his community:

> This is one of those rare chances in school where you actually get to bring your regular daily life into a subject. If you usually think of research at school, most of the time it's just out of a book, it's out of an article online, it's out of something on the internet. You're just sitting there reading about it. But the thing I liked about this phone project— what I really really enjoyed—it gives you the opportunity to literally just walk around the world outside of you…"Oh! *I* am the one! I'm not the one *just reading* the article, but I'm actually the one *writing* the article!"…Like a scientist, you know, the world's first scientist didn't start out by just reading an article about science…He actually had to go out there and do the research himself. So, this really helps us because the [MyData] thing, we actually had to go out there and *find* the advertisements. And it could be challenging at times, but the rewards were definitely worth it. You get the experience to actually know what it's like to get research…no one's telling you what you're doing…you actually got to be a part of it. (James, C.Int3a.5.14.12)

Indeed, finding that connection between academic research and personal community life proved an important tool for helping students learn about data, feel empowered as researchers, and enjoy the process at the same time.

Students Learning "How to do a bar graph thing" and "[T]hat everybody snacks a lot"

Students made important gains in their understandings of data and research. Yet, one may also wonder: Did students learn new data analysis skills? If a central purpose of the MyData Unit was to teach students how to identify, create, and analyze bar plots, histograms, word clouds, etc., then was this goal achieved?

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When asking students about what they learned through this unit, very few mentioned learning related to specific data analysis skills (e.g., How to create graphs and analyze them, etc.). The handful of students who did mention learning graphing skills stated things like, "I didn't know how to make a bar plot before" (Carlos, C.Int1.5.9.12) or "I learned a lot about how to do data analysis. Like I knew how to do it in Excel, but I didn't know how to do the graphs or make charts" (Lisa, C.Int4.5.17.12) or "I learned…how to graph it and analyze it…the graphs and word cloud" (Lucrecia, C.Int15.5.24.12) or "we were able to connect it to JGR, and then we would just see the graph. I think that was fun" (Juliette, M.Int3.6.8.12) or "[I learned] How to do a bar graph thing…I thought it was going to be hard…But it's easy and I know how to do those" (Julieta, P.Int10.5.11.12). While these students' descriptions about learning how to create graphs were important, those who mentioned "graphing" as a new idea learned through the unit were a minority. Similarly, only two students described learning new ways to analyze graphs. Ruby noted, "The thing I learned is more of how to organize [data] and how…you can make questions and then get the data to give evidence for the questions that you found to see if it's supported in the data" (Ruby, C.Int6b.5.22.12) and Enrique commented, "I learned how to interpret data and graphs. And how different data could…relate to each other" (Enrique, M.Int11.6.11.12). Most students were less concrete about their data analysis learning.

These few student interview comments about graphing and data analysis raise three important issues to consider. First of all, Carlos, Lisa, and Julieta's emphases on learning how to create bar plots, graphs, and charts suggest that they were *not* exposed to graphing and data analysis skills by the time they reached 10th-12th grade. This is surprising since passing Algebra I is a prerequisite for enrolling in Discovering Computer Science. It is disconcerting that several students never made bar plots before this course.

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Secondly, the lack of student interview responses regarding graphing and data analysis skills may not actually mean that students failed to learn such skills. In fact, we should consider the phrasing of my interview questions and the temporal context of the MyData Unit during which student interviews took place in order to better understand why so few statements were made regarding data analysis and graphing. In interviews, I asked the question "What have you learned by doing this project with the mobile phones?" This question was asked near the end of the unit as students were preparing their final projects or completing analyses of class data. As such, students were either in the midst of thinking about the results of their data collection regarding snacking and advertising, or had just completed their projects. In light of my interview question phrasing and the period during which I interviewed students, it begins to make sense that most students talked about the results of their snacking or advertising research rather than discuss the skills learned to do such research. For example, students mentioned: "The main thing I learned is that we're eating really really unhealthy foods" (David, P.Int2.5.7.12); "I learned what's healthy, what's not" (Belén, P.Int6.5.9.12); "I didn't think that people would eat that kind of junk food that much" (Olimpia, C.Int13.5.30.12); "I realized, 'Wow! A lot of us don't know what healthy is!'" (Juliette, M.Int3.6.8.12). Others who focused on the advertising project stated: "I learned what people are being exposed to: all the advertisements…[and] fast food companies put on billboards; food that seem to be healthy, but then they're not" (Eddie, C.Int9a.5.24.12); "I started looking more around and saw that there were just a whole bunch of advertisements just everywhere" (Lisa, C.Int4.5.17.12); "I learned more about advertisements and how people advertise and what they do to advertise, how they try to grab peoples' attention" (Hyun, C.Int14b.5.24.12). Most students talked about their interpretations of the data collected rather

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than the skills employed to interpret the data. Perhaps I should have asked more specific questions related to data analysis and graphing skills in student interviews.

Yet this brings us to a third important consideration: Did students' comments regarding snacking or advertising reveal any ideas or skills crucial to computer science and data analysis? A closer examination of students' discussions about snacking and advertising suggested students *were* learning important ways of thinking about data, data analysis, and computational thinking practices through their research projects. Consider, for example, how Alberto talked about his snacking learning:

> I think we learned that not a lot of people eat very healthy and…how much people spend on junk food, how much they spend on healthy food…who they eat it with, where. [And] I think it's really important because I think it could help people out to have a healthier life. (Alberto, P.Int3.5.8.12)

In this comment, Alberto goes beyond noting that people don't eat healthy food to highlight various snacking-related practices helping him come to this conclusion. He talks about the amount of money spent on junk food, who people eat with, and where they eat to underscore his research finding that people eat unhealthy foods. This suggests his understanding that a research finding such as "people eat unhealthy food" needs to be supported by behavioral data.

Or consider how Nico learned that "[Students] don't know how to label [snacks]…they probably didn't even look at the calories or the carbs that it had. So that if it looked very delicious…They would [label] it's healthy" (Nico, M.Int8b.6.1.12). Nico's description of students' data collection practices—mislabeling unhealthy food as healthy simply because it looked tasty—suggests that he was beginning to think more critically about data collection processes. He was pointing out a limitation in the research methods as well as the fallibility of student self-reporting without explicitly stating that he had learned this research skill.

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Another student reflected important learning regarding how to connect research to its the social context. This is an incredibly important skill for any data analyst or computer scientist who must understand the perameters of a problem before attempting to solve it. Hector noted, "I learned that most people here eat junk foods because there's a lot of corner stores…There's not that many supermarkets around, so not that much fruits" (Hector, P.Int9.5.22.12). Hector related this acknowledgment to the fact that "I learned how to connect the data…[if] there's a lot of liquor stores, there'll be a lot of Cheetos in the community" (Hector, P.Int9.5.22.12). In these comments, Hector shows a new understanding about how data analysis requires one to relate data back to the social context. Hector was recognizing how the lack of healthier snacks (fruit, for example) suggested a lack of access to these types of snacks since the closest supermarket selling fruit and vegetables was far away. Again, this deeper data analysis skill Hector was applying to his thoughts on snacking was not explicitly stated as what he "learned," but was clearly new learning couched in his understanding of results from the snacking research.

Similarly, Carlos made an important leap in data analysis when reflecting on the types of food people eat:

> [I am] more interested [in doing research] because I start realizing with the snack thing that I've been eating a lot of food that are just from manufacturing. Not even people cooking. I'm eating cereal and fast foods. And I started really think[ing]: they don't cook for me, do they? Not at home. So, I start[ed to] realize that I should do something about it because I know that's not healthy. (Carlos, C.Int1.5.9.12)

Here Carlos emphasized not only a new interest in doing research, but also that most of his snacks were processed foods and rarely made at home. This realization suggests that Carlos developed valuable data analysis skills that allowed him to see an important trend in the data that added a new variable to his study. This valuable research skill was not explicitly stated but still came through in Carlos's comments.

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Maura's reflections on advertising also suggested that she had acquired new research skills in analyzing data:

> [T]here are a lot of advertisements around, and different ones especially…the same advertisements can be found in this certain area…Like in [our neighborhood], we see advertisements for movies especially and plays…[but] when you go down the other road, you can see there's fast food advertisements and different kinds….if you go to a residential area, probably there it would be different. (Maura, C.Int5b.5.17.12)

Again, while this sounds more like a research finding rather than a new research skill learned through the MyData Unit, Maura's point about geographically-based, targeted advertising reflects her engagement with more complex data analysis skills that situated advertising commonalities in their neighborhood contexts.

<u>Student Survey Results - Increased Attraction to and Self-Efficacy with Computer Science</u>

Seven total schools piloted this MyData curriculum in the 2011-12 school year. A program evaluation team from the National Center for Research on Evaluation, Standards, and Student Testing (CRESST) and the Center for the Study of Evaluation (CSE) designed a student survey to assess students' access to technology at home, the comfort with which they used MyData-specific technology (e.g., mobile phones, software programs, etc.), students' attitudes toward computer science, students' self-efficacy with computer science, and their abilities to answer computational thinking questions about a *Facebook* research scenario and community park research task (See description of survey in Chapter Four; Ong et al., 2012). The survey was administered to students both before and after the unit through an online survey system.

In Ong et al.'s (2012) project evaluation describing the results of this student questionnaire administered to all seven schools—including Midtown, Presidential, and City High Schools—ease of technology-use in the curriculum correlated positively with attraction toward and self-efficacy in computer science. Attraction to computer science and self-efficacy scores

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with computer science also positively correlated with computational thinking assessment scores from the *Facebook* and community park scenario tests (Ong et al., 2012, p. 50). Following this unit, students showed a slight increase in attraction to computer science and felt better about their abilities in computer science (Ong et al., 2012, p. 51).

Interestingly, when separating out the student survey responses from Midtown, Presidential, and City High Schools, it appeared that many of the positive learning trends and attraction/self-efficacy scores found in CRESST's report could be attributed specifically to Mendoza, Torres, and Santos's classrooms. Consider the graph of "attraction to computer science" scores below:
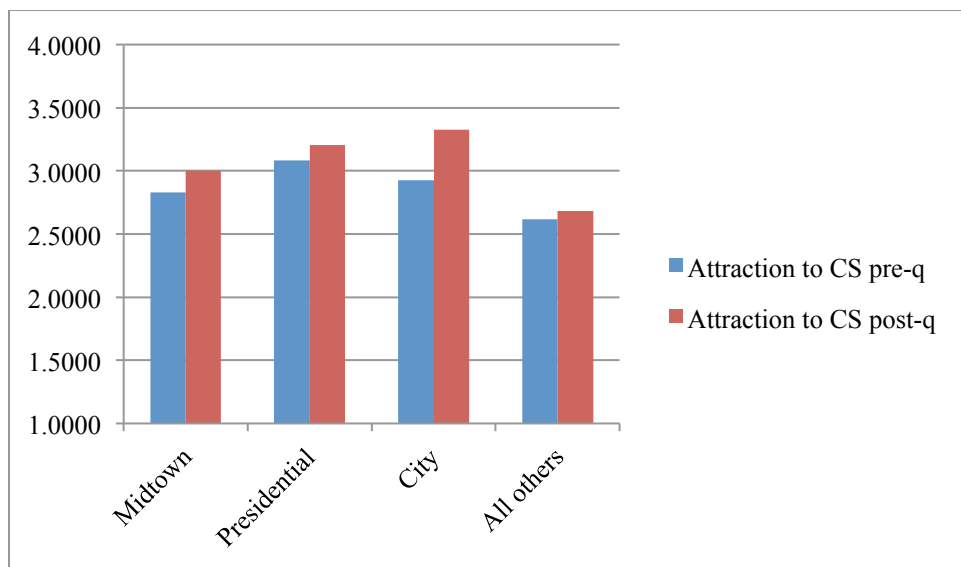
Figure 8.1*: Student attraction to computer science scores on pre- vs. post-surveys.*

As visible in the graph above, students at Midtown, Presidential, and City High Schools all had higher average attraction to computer science before the unit than the other participating schools. Their attraction to computer science also increased after the data analysis unit to much higher levels than the average for the other participating schools.

The self-efficacy scores for students' questionnaire results show parallel trends:

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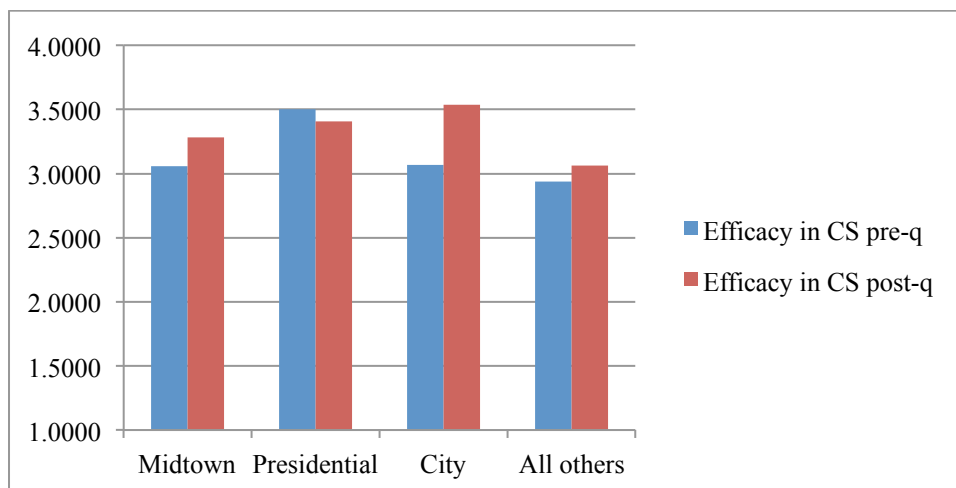
Figure 8.2*: Student self-efficacy scores on pre- vs. post-surveys.*

According to the graph in Figure 8.2, all three dissertation schools had generally higher rates of student self-efficacy in computer science than the other participating schools. At Midtown and City High, students' self-efficacy scores in computer science increased to a significantly higher level than the average score at the other schools. What's interesting to note, however, is that Presidential High's students dipped slightly following this unit. This may be due to the fact that students in Mr. Torres's class at Presidential High never got to create their own final projects and experience independent data analysis. Students analyzed data as a class under Mr. Torres's guidance. Perhaps if the students had the opportunity to struggle with data on their own and create final projects, they may have had even higher self-efficacy in computer science scores. Still, students' self-efficacy scores at Presidential High were still, on average, higher than the other participating schools.

Regarding the computational thinking *Facebook* and community park research tasks, results show that students at Midtown, Presidential, and City High Schools all improved significantly after experiencing the MyData Unit. Interestingly, despite the fact that Presidential High students reported decreasing self-efficacy in computer science after the data analysis unit,

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their performance on the computational thinking tasks were always higher than the average of the other participating schools and higher or equal to City High. See the graphs below:
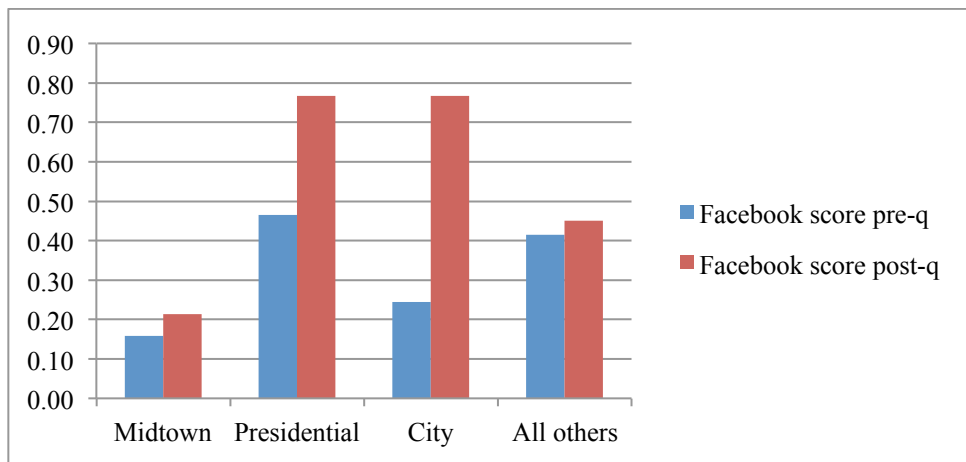
Figure 8.3: Students' computational thinking scores on the Facebook research scenario.
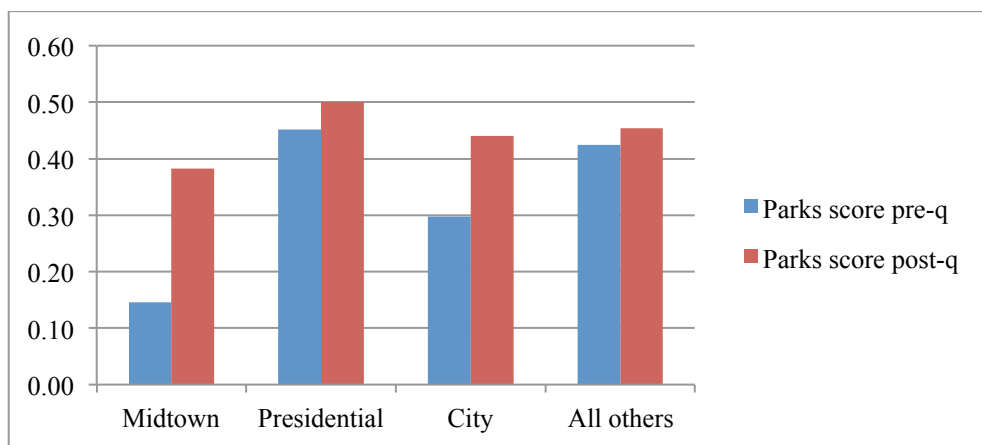
Figure 8.4: Students' computational thinking scores on the community park research scenario.

As visible above, for the *Facebook* research scenario, all three dissertation schools showed increases in their abilities to complete the questionnaire task after completing the data analysis unit. The increase in scores were particularly visible for Presidential and City High students that rose above the average of all other schools. It is unclear why Midtown High students had lower base scores on both tasks compared to the other participating schools. Pre- and post-scores on the *Facebook* task look much lower than all the other schools. Yet post-scores on the community park task approached the average of all other schools. It may be that Midtown's strongest data

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analysts were absent when this post-survey was administered. Unfortunately, since these surveys were anonymous, it is impossible to see which students completed the surveys and were weak or strong at this task.

These survey findings suggest that the MyData Unit had a generally positive impact on all the participating students and, most particularly, at Midtown, Presidential, and City High Schools.

Examining Student Projects – Student Learning Beyond the Interviews and Surveys

While student testimonies are compelling and the students' self reports on attraction toward, and self-efficacy with computer science are important, how exactly did students *demonstrate* their learning in this data analysis unit?

A closer look at students' final projects and their ways of presenting these projects to an audience reveal important data analysis and critical thinking skills in relation to computer science. More specifically, multimodal analyses of student projects and presentations captured on video illustrated many of the computer science practices defined by the College Board (2012, p. 1) that are detailed below:

1. Connecting Computing
   a. Identification of impacts of computing.
   b. Description of connections between people and computing.
   c. Explanation of connections between computing concepts.
2. Developing computational artifacts
   a. Creation of an artifact with a practical, personal, or societal intent.
   b. Selection of appropriate techniques to develop a computational artifact.
   c. Use of appropriate algorithmic and information-management principles.
3. Abstracting
   a. Explanation of how data, information, or knowledge are represented for computational use.
   b. Explanation of how abstractions are used in computation or modeling.
   c. Identification of abstractions.
   d. Description of modeling in a computational context.
4. Analyzing problems and artifacts
   a. Evaluation of a proposed solution to a problem.

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b. Location and correction of errors.
        c. Explanation of how an artifact functions.
        d. Justification of appropriateness and correctness.
   5. Communicating
        a. Explanation of the meaning of a result in context.
        b. Description using accurate and precise language, notation, or visualizations.
        c. Summary of purpose.
   6. Collaborating
        a. Collaboration of participants in solving a computational problem.
        b. Collaboration of participants in producing an artifact.
        c. Collaboration at a large scale.

These practices were not demonstrated at equal depth across all students in all three schools. Some students appeared to excel while others struggled with data analysis and these computer science practices.

In the sections that follow, the final projects and presentations for students at Midtown and City High are described at length. Unfortunately, Mr. Torres did not have his students complete final projects for this unit due to external stressors and time constraints. However, the positive impact of the ways he guided students through data analysis practices as a class was visible in his students' improved computational thinking scores in the CRESST questionnaire tasks.

Midtown High School Final Projects

At Midtown High, twenty-six students borrowed phones and participated in data collection. Of these twenty-six students, sixteen completed final projects. Of these final projects, eleven students created posters, two students created Powerpoint presentations, one student created a website, one student created a movie, and one student created an animation in Scratch[18] coupled with two videos demonstrating his use of Excel to calculate average health levels. This range of final projects is shown in the table below:

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[18] Scratch was developed by researchers at MIT designed to introduce people to the ideas behind computer science programming through a simple to use, visual, programming language. (See www.scratch.mit.edu)

Figure 8.5: Midtown High School Final Projects.

	Poster	Powerpoint	Website	Movie	Scratch + Movies	Total
# of Students	11	2	1	1	1	16

The complexity of Midtown High students' data representations (in the form of graphs constructed through the JGR/Deducer data analysis program) varied tremendously in these final projects. None of these students subsetted their class data before building plots or graphs. Furthermore, while a little over half of the students presented more complex, multi-variable graphs, many did not. This varying graph/plot complexity is shown in the table below:

Figure 8.6: Midtown High School Plot/Graph Complexity.

# of plots/graphs	0	1	2	3	4	5	6	7	8	9
# of projects	1	3	6	2	2	0	0	0	1	1
# of projects containing 2-variable plots	0	1	3	1	2	0	0	0	1	1
# of projects including sub-setting of data	0	0	0	0	0	0	0	0	0	0

The majority of student projects at Midtown High only included a total of two or fewer plots or graphs. Six students included three or more plots or graphs in their projects, of which five included more complex, 2-variable plots.

Coding of these projects revealed that the majority of students provided fairly accurate interpretations of their graphs and plots. Fourteen of the sixteen projects offered simple and straightforward interpretations of their graphs that showed an understanding about how to read these graphs. For example, Lena accurately interpreted two pie charts on her final project poster: one pie chart depicted the total number of snacks eaten alone, with classmates, with family, with friends, and with "Other," while a second pie chart depicted the total number of snacks eaten at home, at parties, at restaurants, at school, and at "Other." Lena correctly explained: "The

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conclusion I made of the snacking habits of Metro City area high school students[19] is that they eat most of their snacks at <u>home</u> with their <u>families</u>" [underline included in the original text]. Here Lena demonstrated the computer science practices of "developing computational artifacts" (the pie charts) and "communicating" what they mean by explaining her research results in context. The plots from her poster are shown below:

Figure 8.7: *Lena's pie chart showing with whom students ate their snacks.*

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[19] Lena's statement focusing on "Metro City area high school students" seems too broad a generalization since her project only examined data from herself and her twenty-five classmates. However, this sentence phrasing was the result of her teacher's final project framing. When introducing the final project, Ms. Mendoza noted that students would be examining the snacking habits of "Metro City area high school students." During class, one student challenged the idea that they could make conclusions about "Metro City students" because they did not have data from *all* Metro City area high school students and only the snacking data from their small classroom (M.FN.5.1.12). After acknowledging that this was true, Ms. Mendoza insisted that students should consider themselves among the "Metro City area high school students" population, and therefore include such phrasing in their projects. This was why students like Lena noted that "Metro City area high school students" were the focus of analysis in these final projects despite the fact that the research sample size did not include all Metro City area high school students.
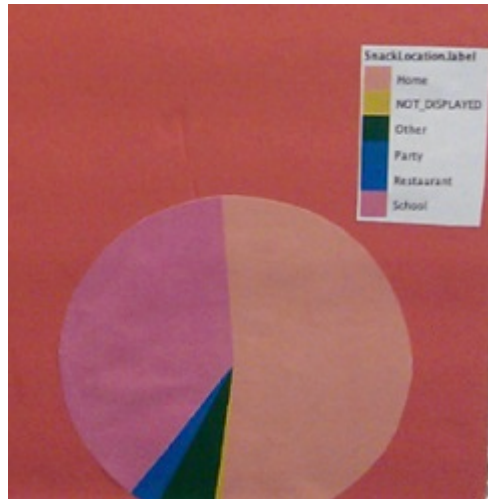
Figure 8.8*: Lena's pie chart showing where students ate their snacks.*

While most students offered correct interpretations of their plots as Lena did regarding her pie charts, three students made unfounded assumptions about what their graphs or plots meant in relation to bigger data analysis applications. Consider, for example, Julio's poster below:
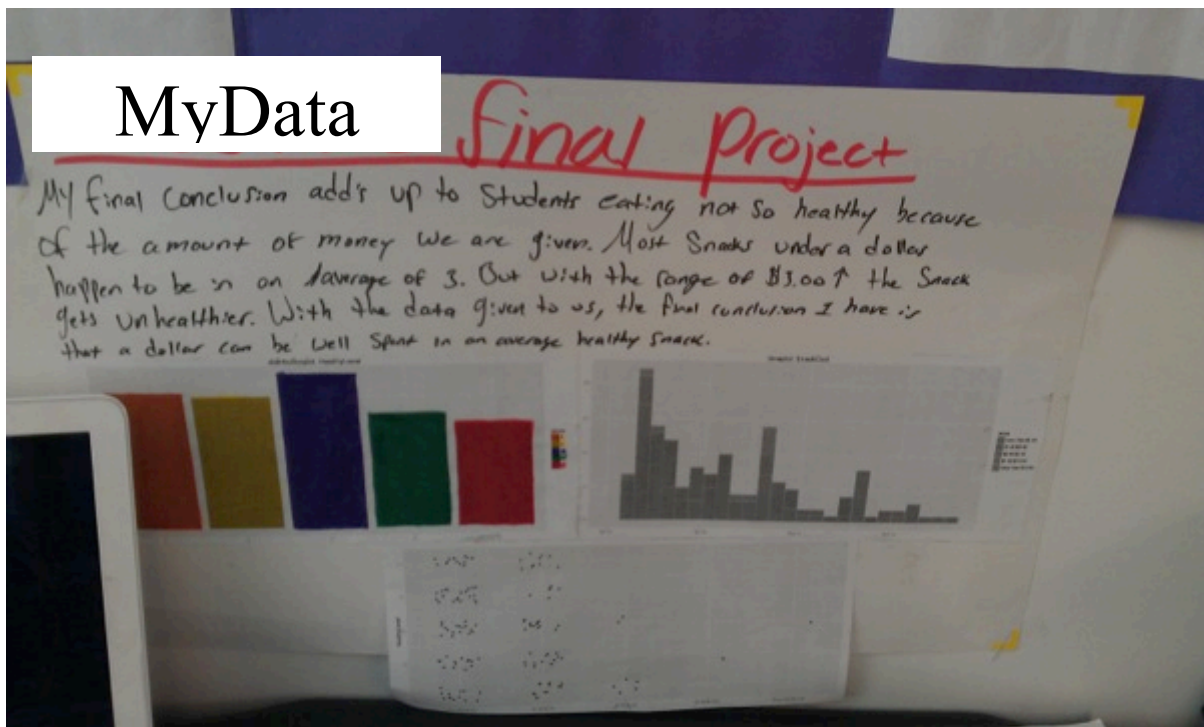
Figure 8.9*: Julio's final project poster (with title blocked out to protect student privacy).*

The three graphs shown on Julio's poster include: 1) a bar plot depicting the number of snacks in each healthy level (colored bar plot to the far left); 2) a bar plot showing the cost of each snack recorded for every day over the data collection period (grey bar plot on the top right); and 3) a scatter plot showing snack cost on the x-axis and healthy level on the y-axis (bottom plot). Based on his graphs, Julio noted that students were not eating very healthily. While it appears true that slightly more snacks were rated either a "1" (very unhealthy) or "2" (unhealthy), the total number of unhealthy snacks was not significantly higher than medium or healthy snacks. This suggests that there was no clear trend in healthy level for students' snacks. Furthermore, Julio made the sweeping conclusion that students were not eating very healthy because of the amount of money they were given, noting: "with the range of $3.00↑ the snack gets unhealthier." While this was a very compelling argument, it was not well-supported by Julio's graphs. It is true that the scatterplot (bottom graph) showed how five of the nine total snacks labeled greater than $3.00 were considered "very unhealthy" or "1," however Julio does not consider how these snacks were very few in number compared to the total number of snacks recorded. Furthermore, he did not address how three of the nine snacks were labeled as "medium healthy" or "3" which seems significant in comparison to the five "very unhealthy" snacks. Finally, snacks in the $0-$1 and $1-$3 ranges appeared to be evenly distributed in every healthy level according to Julio's scatter plot. This would suggest that cheap snacks were neither healthy nor unhealthy. More data would need to be collected to confirm Julio's conclusion, but he does not address this fact on his poster. Thus, his conclusions did not seem fully supported by his graphs.

Despite some students making weaker conclusions based on their data, most students were accurate in their graph/plot interpretations. However, the depth with which students demonstrated the "connected computing" computer science practice by considering these

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interpretations when applying them to the greater community or research contexts varied significantly. Only three students actually asked new questions or offered suggestions for future research and community action that were firmly rooted in their research findings. For example, Larry created a movie that included four plots interspersed with written interpretations of the plots as well as images/video found on the internet. The background music Larry chose was The Clash's song *Kola Kola* that compares the impacts of advertising to drug addiction and violence. Larry's plots included: 1) a bar plot of the total number of snacks in each healthy level; 2) a scatter plot of snack cost; 3) a 2-variable box plot comparing healthy level of snacks and who they were eaten with; and 4) a map showing where each snack was eaten. Using these plots, Larry concluded that students were not sure how to label the healthy levels of their snacks, that the food chosen was dependent on the money students had available, that the healthy level of snacks varied depending on who students snacked with, and that most snacks were eaten on school campus. Following these interpretations, Larry demonstrated some deeper thinking and computer science practices related to "connected computing" by suggesting how to apply these findings to life at his school. He noted that to ensure students eat healthier snacks, the school should provide healthier options in vending machines or at the cafeteria since students ate most of their snacks at school with the small amount of money they had available. This is visible in the video stills below:

a.

b.

c.

d.

e.

f.

g.
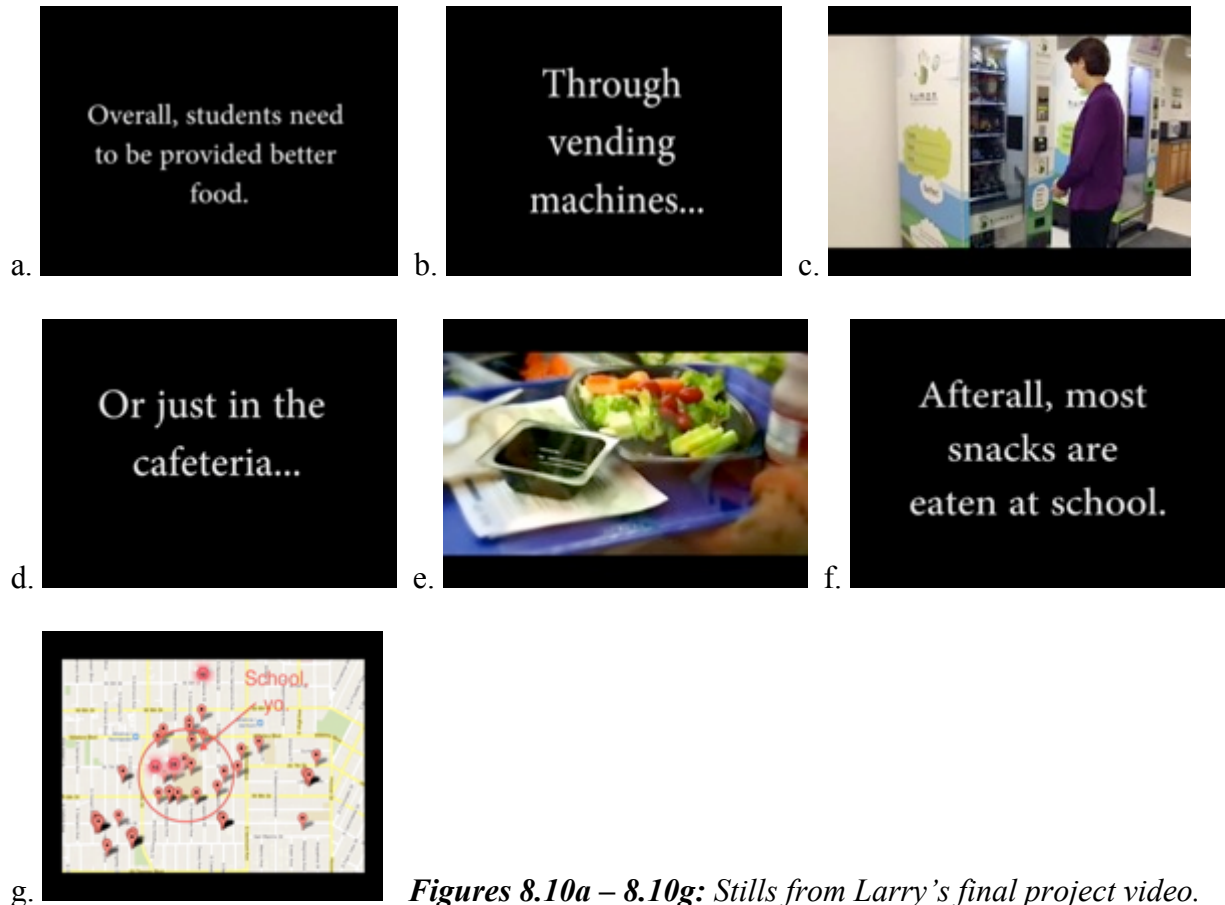
Figures 8.10a – 8.10g: Stills from Larry's final project video.

Beyond the complexity of his film that showed careful data analysis and new media skills, Larry's work was an example of how some students applied higher order thinking skills to their final projects.

Another example comes from Anthony who tried to make conclusions about the healthiness of students' snacks with class data. Through his analysis process, Anthony realized that one cannot assume that all people define "healthy" in the same way. As such, Anthony included a definition for "healthy" in his presentation as shown below:

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(A) Base on our own experience through survey, snacks are relatively were almost always consumed many times by more than 90% of us, ranging from 1 to more than 10 snacks per day.

Most of the snacks we consume in average, were basically unhealthy, *The best definition of 'healthy' I could provide here is, the one which wouldn't cause any 'harm' in your body (a risk to any kind of illness), or perhaps snacks that contain/building up lot of calories.

Figure 8.11: *Anthony's final project (Scratch animation) defining "healthy."*

Anthony used critical thinking skills—by challenging assumptions that people share the same definition of healthy or that viewers of his work would understand what he meant by "healthy"—while also illustrating computer science practices in "communicating" by explaining his results in context. This was why he included the sentence: "The best definition of 'healthy' I could provide here is, the one which wouldn't cause any 'harm' in your body (a risk to any kind of illness), or perhaps snacks that contain/building up lot of calories." This decision on Anthony's part was particularly compelling because he was a recent immigrant from Southeast Asia and an English Language Learner. Thus, this definition for "healthy" reveals how he made an effort to find and share a definition for a term that he recognized may not mean the same thing to all people in different languages or areas of the world.

Anthony's way of thinking about the perspectives of his project viewers was also evident in his final project videos. Instead of just showing a graph (as most other students did) and

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assuming that viewers would accept the graph as true, Anthony created short videos to illustrate *how* he created his graph. These videos were created using a screen capture software that recorded his real-time use of Excel to calculate average healthy levels for all snack entries for each day, as well as the overall average healthy level for all snacks. His effort to show viewers how he calculated mean healthy levels reflects Anthony's desire to be transparent about his data analysis process in this final presentation. Instead of just stating his conclusions about student snacking habits, he used metacognitive skills to reflect on his *process* of developing these conclusions. In this way, Anthony demonstrated the computer science thinking practice of "abstracting" by demonstrating how data are represented for computational use and modeling. This focus on process over answer reveals valuable computer science skills as noted by Wing (2006), "Computational thinking involves solving problems….using abstraction and decomposition when attacking a large complex task…It is separation of concerns" (p. 33). Anthony's process of breaking down the definition of "healthy" as well as his individual methods for calculating average healthy levels distributed in his graph reveal the computational thinking "separation of concerns" and "decomposition" approach to solving problems that were highlighted by Wing (2006).

A Closer Analysis of Three Midtown High Final Projects

To gain a better grasp of the computer science practices, data analysis, and research skills students did or did not engage through this unit, let us examine three final projects from Midtown High more closely. These three projects were representative of a typical weak project, a typical average project, and a typical excellent project in Ms. Mendoza's classroom.

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1. Annie – An Example of Surface Analysis

Annie created a poster for her final project that included a single plot. This plot was a pie chart of the total number of snacks recorded under each healthy level as shown in the poster below:
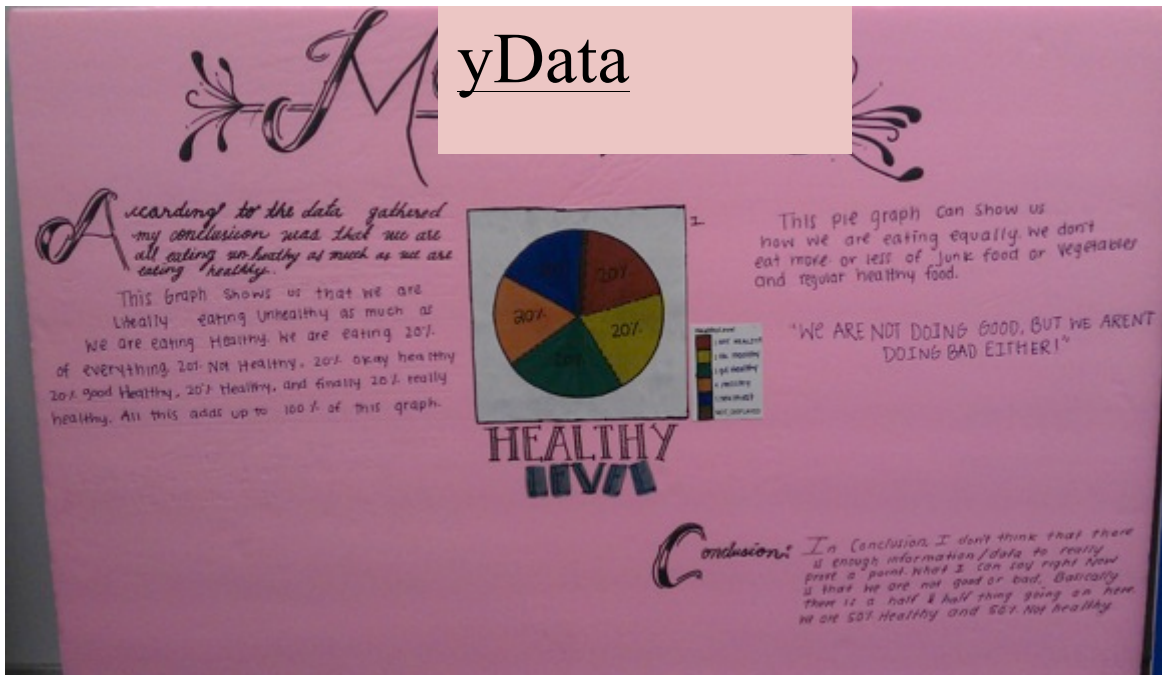
Figure 8.12: *Annie's final project poster (with title blocked out to protect student privacy).*

Annie made her pie chart as clear as possible by including not only percentages for each section, but also a key for making sense of each color in the pie:
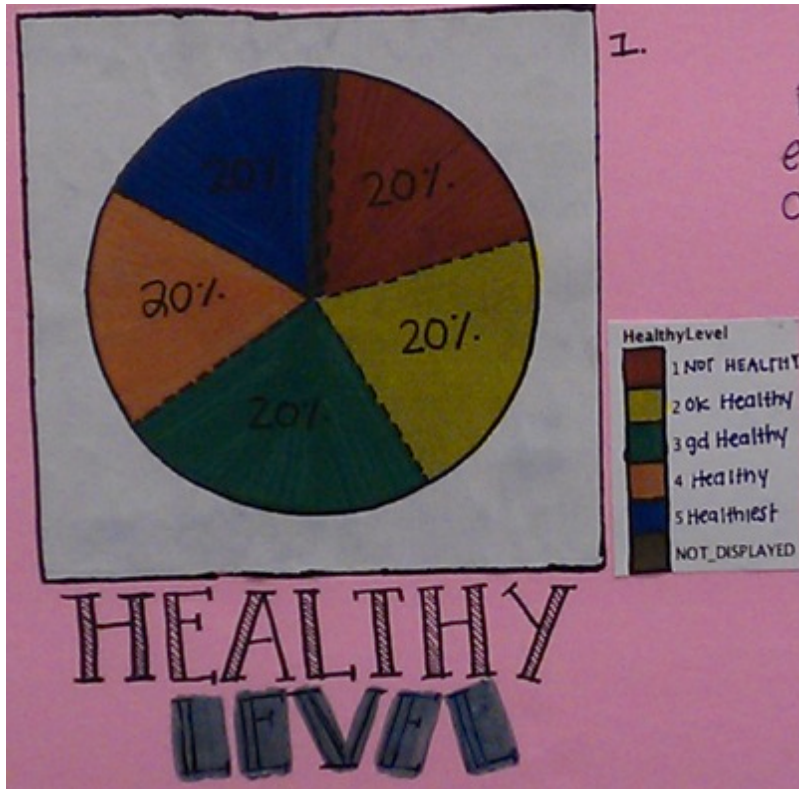
Figure 8.13: *A close-up of the center of Annie's poster focusing on a pie chart of healthy levels.*

Annie positioned this pie chart in the center of her poster, emphasizing its importance for making

sense of students' snacking habits. The key explaining what each wedge of the pie chart

represented also shows her effort to help viewers understand what each healthy level (1-5)

actually meant. Using more informal terms, Annie wrote that "1" represented "Not Healthy," "2"

represented "OK Healthy," "3" represented "gd [good] Healthy," "4" represented "Healthy," and

"5" represented "Healthiest." Also, Annie clearly paid attention to the aesthetics of her poster in

not only the positioning of these chart images, but also her color choices for the pie chart and her

hand-drawn font design for "Healthy Level" beneath the pie chart. The colors and design were

employed to catch the viewer's eye in comparison to the text surrounding it.

However, a closer look at this pie chart reveals a problem: the percentages marked on

each wedge of the pie chart are inaccurate. Annie marked each section as exactly 20% of all

snack entries. In reality, each healthy level (from "1" or "very unhealthy" to "5" or "very

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healthy") did not actually add up to exactly 20% per category. While the total number of snacks in each healthy level category was pretty similar, none were exactly the same. In fact, the middle level (3) had the highest number of snacks at 24% of the total, while the healthiest level (5) had the least number of snacks at 16% of the total. Thus, Annie incorrectly represented and interpreted the distribution of healthy levels in her class snacking data. This incorrect interpretation was further emphasized in her plot interpretation shown in the image below where Annie stated "This Graph shows us that we are lite[r]ally eating unhealthy as much as we are eating Healthy. We are eating 20% of everything."
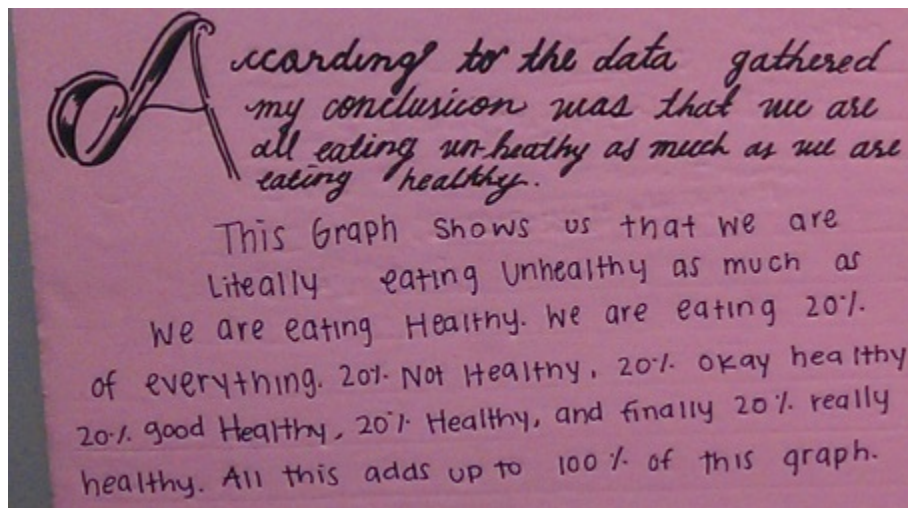
Figure 8.14: A close-up of Annie's major conclusion and interpretation of the pie chart.

Of course, one might argue that there was not enough of a difference between the total number of snacks in each healthy level; the difference between 16% (very healthy) and 24% (very unhealthy) may not seem significant enough to make a strong argument about whether students were eating healthy or unhealthy foods. This was perhaps why Annie proceeded to conclude: "According to the data gathered my conclusion was that we are all eating unhealthy as much as we are eating healthy." In fact, to the right of her pie chart, Annie included the following text:
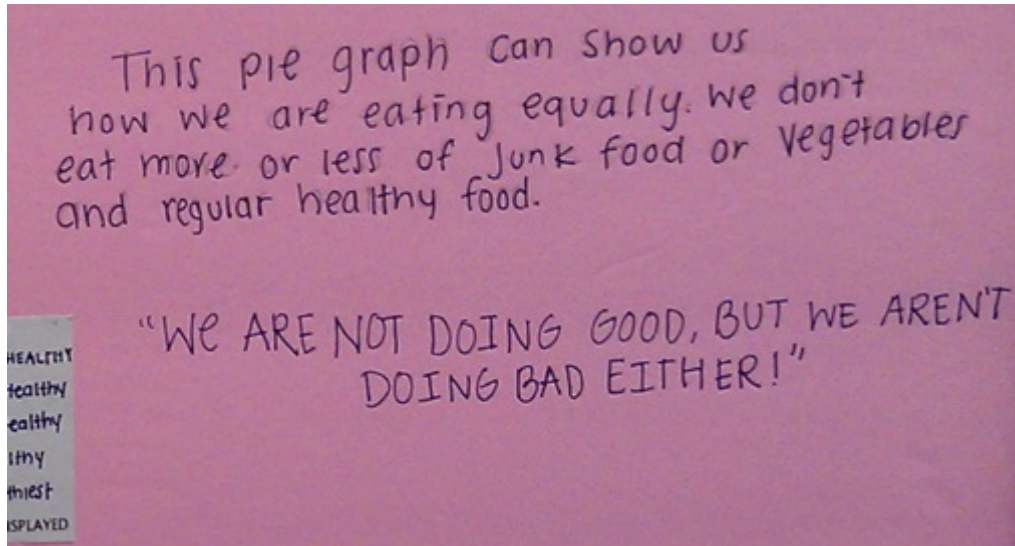
Figure 8.15: *A close-up of Annie rephrasing her interpretations of the pie chart.*

Restating her interpretation of the graph, Annie noted that students were "eating equally." She

proceeded to make an assumption that healthy foods included "vegetables" and described the

opposite of "junk food" as "regular healthy food." This sentence clarified what Annie defined as

healthy and unhealthy, yet it remained ambiguous whether or not all students agreed with these

definitions. For example, would vegetables cooked in lard be considered "healthy" to all

students? Or would multigrain pita chips be considered "junk food"? Annie did not seem to

make any strong decisions here as further emphasized by her noncommittal comment in capital

letters, "WE ARE NOT DOING GOOD, BUT WE AREN'T DOING BAD EITHER!" (Figure

8.15).

Annie's insecurity about her findings became particularly visible in the video footage of

her presentation. This video footage captured Annie presenting her project to a classmate

(Natalia) on June 8, 2012. As Natalia stood still to the right side of the camera frame, staring at

Annie's poster, Annie's nervousness began to shine through her physical movements: Annie had

her arms crossed tightly with her hands clasping opposite elbows, she swung her body left and

right while smiling and keeping her gaze fixed away from both Natalia and the camera. Before

speaking, Annie giggled and then sighed loudly. Finally, she proceeded to stumble over her explanation of the poster: "Okay, so like, um, I was telling yoooou…I came to…Okay, so I see…I look at this as a hundred percent." Annie drew her hand over the pie chart, then explained that every section of the pie chart added up to "twenty percent" while reading aloud the different categories in the chart key for Natalia and the camera. Noting: "So basically it's all to 100%" Annie noted "we're not *that* healthy, but we're not really that *un*healthy either." Then Annie repeated the idea that there was 20% of each category. While Annie may have just been camera shy, this first minute of her presentation suggested that she felt uncertain about her research findings.

While Annie's inaccurate pie chart and interpretation of this chart seemed surface-level and insecure, the bottom right panel of her poster reveals that Annie had an emerging sensibility about the complexities of data analysis. In this section of her poster, Annie noted: "In conclusion, I don't think that there is enough information/data to really prove a point." Her complete statement is visible in the image below.
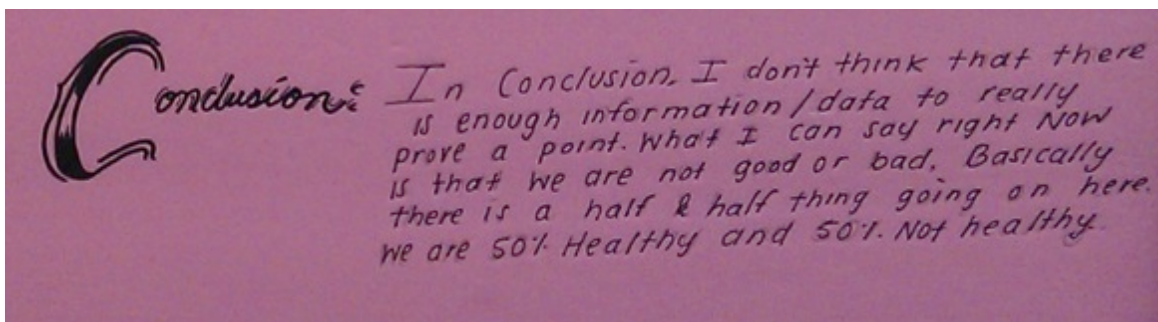
Figure 8.16: *Close-up of Annie's final conclusion that more data is needed "to prove a point."*
She did not believe that a definite conclusion about students' snacking habits could be made with the data available, which reveals why she did not believe one could say that students were eating primarily unhealthy or healthy snacks. While Annie never articulated why she needed more data

to make a conclusion, this statement on her poster reflected a budding sensibility about sample size.

Classroom Context for Annie's Learning – Peer Support

Yet how did Annie learn to question the data? Where did her beginner data analysis skills come from?

A closer look at Ms. Mendoza's classroom reveals how Annie's learning was facilitated through peer support in ways that mimicked Ms. Mendoza's own teaching style. This is described in the vignette below:

On June 6, 2012—two days before the final projects were presented—Annie was struggling to create her final project. She had not yet created any final graphs or come to any clear conclusions about the class snacking data. On this particular day, Annie arrived to class and, as she sat down at a laptop, she turned to Nico for help accessing the class data. Nico handed her the Ms. Mendoza's jump-drive that contained a .csv file of all the class data which she proceeded to download to her computer. However, at this point Annie was stuck. She wasn't sure what to do to create graphs with the data. Instead of turning to Ms. Mendoza for help, Annie turned to her friend Julio and asked what to do. Getting up from his laptop, Julio walked over to Annie desk and walked her through opening the JGR/Deducer program, uploading the data set into the software program, and opening the plot builder. Julio proceeded to show Annie how to build a graph, then left her to let her choose which one to make. After some time working alone, Annie decided to make a pie chart just like Juliette's. After Annie created the pie chart, she looked up for assistance and Julio walked over to her desk again and, looking over her shoulder, began to interpret the pie chart. However, Juliette interrupted him and Julio stepped away, allowing Juliette space to assist Annie. Juliette then pointed to the pie chart on Annie's screen and asked, "So what can you say about this chart?" Annie replied, "They're the healthy levels." Juliette nodded her head, replying, "Right. So you can see that each level is kind of equal." Annie agreed and Juliette then pointed out, "So we can't really say that we're eating healthy or not healthy." (M.FN.6.6.12)

Through this interaction, we can begin to see how Annie came to her final project conclusion that the class was eating both healthy and unhealthy foods because of the lack of distinction between the varying healthy levels. Juliette helped Annie make sense of her pie chart in this specific way. What's interesting to note, however, is the process Juliette used to help Annie arrive at the conclusion that "each [healthy] level is kind of equal." While Juliette had the

opportunity to tell Annie from the very beginning how to interpret the pie chart, Juliette did not choose to do so. Instead of saying her own interpretation immediately, Juliette began assisting Annie with the question, "So what can you say about this chart?" This seemingly simple question revealed how Juliette was trying to support Annie in coming to her own conclusion about the pie chart, giving Annie the room to interpret her graph before providing her with an explanation. Interestingly, this facilitation of Annie's thinking mimicked the ways that Ms. Mendoza taught her students throughout the school year.

Ms. Mendoza rarely gave students the direct answers, but instead would support students' processes of coming to their *own* answers using open-ended questions. For example, when teaching students how to use JGR/Deducer to create maps, Ms. Mendoza did not tell students what all the various map-building components represented. Instead, she built a map of students' snack locations using the "Points" option and ask, "What can you conclude just looking at this?" Without ever telling them her own answer, students shared their interpretations, coming to the correct consensus that the map displayed snack locations. Then she moved on to create another map with the "Colored Points" option showing a map key marking different point colors by healthy level. Again, without telling them what the map represented, Ms. Mendoza asked students how they interpreted this map as Nico asked, "What does the key say? 1-5 is health?" And thus, through collective interpretation, students came to the correct understanding that the map showed not only snack location, but also the healthy level of the snacks as marked by color (M.FN.5.22.12). Or on another occasion, Ms. Mendoza gave students an image of a person in a room filled with items. Without sharing her own interpretation of the image, Ms. Mendoza asked students to share their readings, asking, "So in our data [the room image], what are the most

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items related to?" After students shared some ideas, Ms. Mendoza continued to ask open-ended questions such as "What does this data tell? What doesn't it show or reveal?" (M.FN.10.18.11).

Returning to the vignette of Annie and Juliette above, in the same way that Ms. Mendoza supported students in coming to their own conclusions, Juliette began helping Annie by asking her an open-ended question about the pie chart. While Juliette did not give Annie much time to be able to come to her own conclusion, and while Annie's only conclusion about the pie chart was that "They're the healthy levels," Juliette's attempt to let Annie reach her own interpretation showed how students supported each other's learning in ways similar to their own teacher. Unfortunately, Annie took Juliette's comment that "each level is kind of equal" and incorrectly concluded that every section of the pie chart equaled exactly 20%. However, Juliette's support of Annie's pie chart analysis process and final comment that "we can't really say that we're eating healthy or not healthy" apparently helped Annie begin to question the data set. Embracing Juliette's assistance, Annie began to examine the pie chart in a way that questioned whether there were enough data to make a clear conclusion about the healthiness of students' snacks. The support Annie received from both Julio and Juliette was central to facilitating her entry into deeper thinking with data analysis.

2. Dario's Posters – A Typical Example of Emerging Critical Thinking Skills

Dario created two posters for his final project that were haphazardly constructed using whatever materials he could find in Ms. Mendoza's classroom (post-it paper, white-board markers, pencils, glue-sticks, etc.). Dario's completed posters are visible below:

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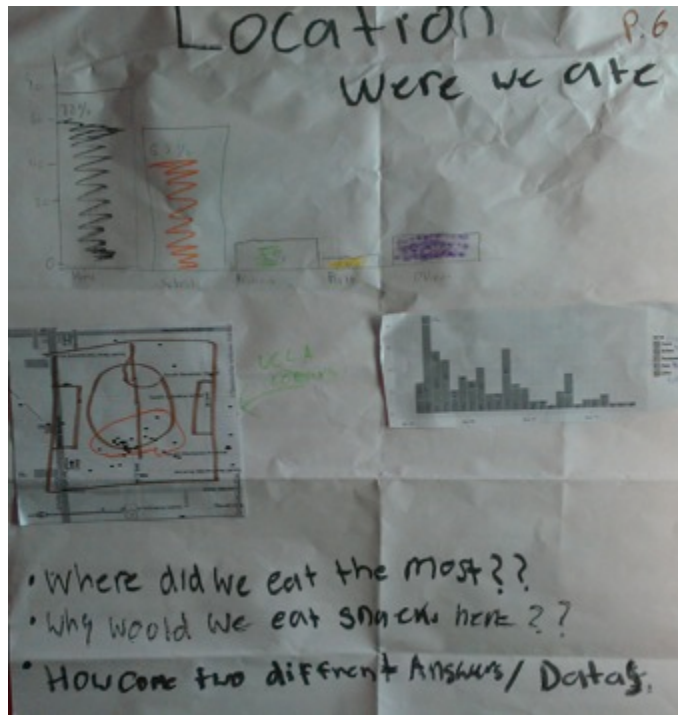
Figure 8.17: Dario's first poster describing snack locations.
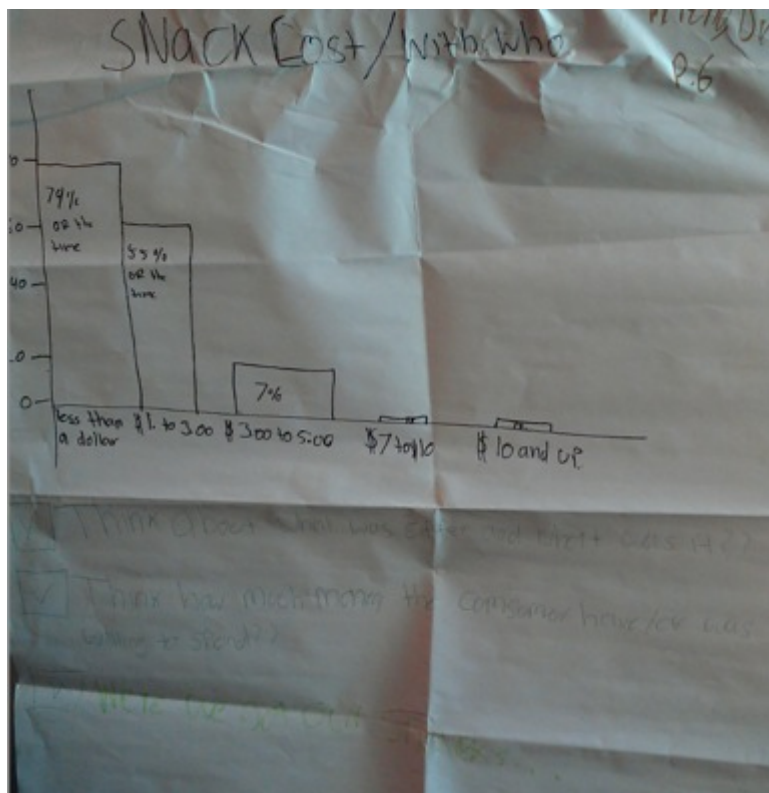
Figure 8.18: Dario's second poster describing snack costs and with whom snacks were eaten.

In the first poster shown above (Figure 8.18), Dario included three different plots, two of which were computer-generated computational artifacts. The first plot at the top of the poster was hand-drawn, depicting the percentage of snacks eaten at home, school, a restaurant, a party, or "other" location. This detail is visible below:

Figure 8.19: *Dario's bar plot of percentage snacks eaten in different locations.*

The second plot visible on the bottom left of the poster showed a computer-generated map where individual snacks were eaten. Dario had drawn a general schema in brown of the school's campus on top of the map to highlight where the different buildings on campus were located. Dario also used an orange marker to circle where the most snacks were located according to the map. This detail is visible below:
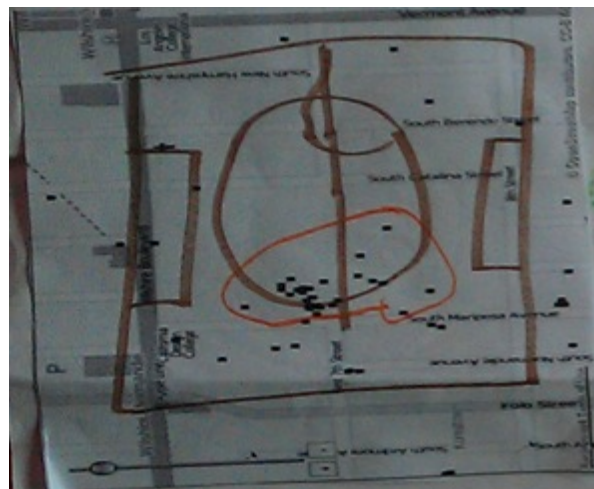
Figure 8.20: *Dario's second plot on the first poster depicting a map of snack locations.*

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The third graph on the bottom right of this poster was a computer-generated bar plot showing the distribution of snack locations (home, school, etc.) by date. Dario had also written on top of this particular plot to match the bar sections with the plot key. On the key, Dario had written the colors for each section and then labeled those same colors (by letter) on the bar plot. This is visible in the image below:
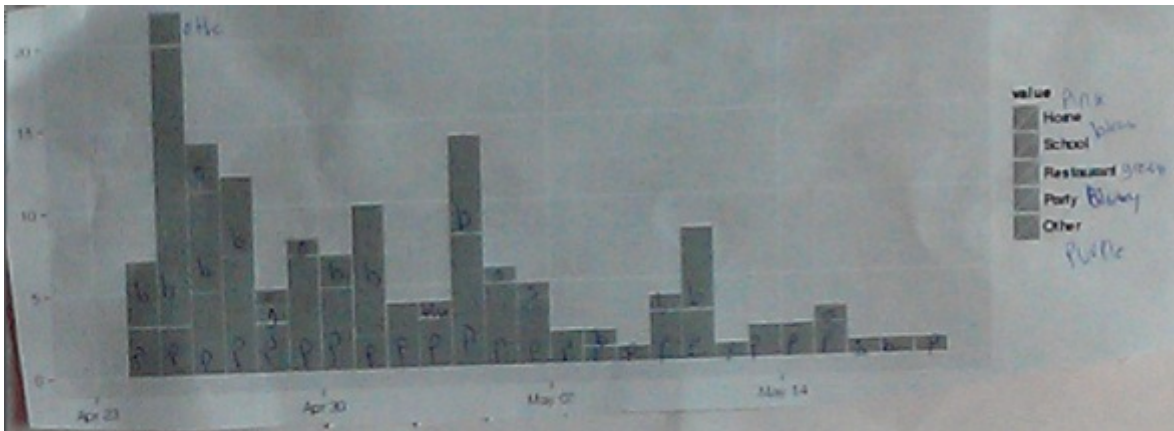
Figure 8.21: Dario's bar plot of snack locations by date.

Below these three plots, Dario listed three questions: "Where did we eat the most?? Why would we eat snacks here?? How come two diffrent Answers/Datas."

While there is no video footage of Dario presenting these posters, his presentation was described in a field note on June 8, 2012. On this day, Ms. Mendoza had organized final presentations as a "gallery walk" in which half the students presented their projects to classmates who walked by to see them, after which the students switched roles and peer viewers became presenters. After rotating through the room and watching Larry's video, I arrived at the back of the classroom where Dario was seated in a chair beneath his post-it posters. The following vignette describes Dario's project presentation:

Dario was sitting quietly, surveying the room when I approached him and asked if he would be willing to share his project with me. Dario smiled broadly and got up out of his seat, agreeing that he would love to explain his posters to me. Gesturing at the first poster entitled "Location were we ate" (shown in Figure 8.17 above), Dario pointed to the map (Figure 8.20)

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that he had created using JGR/Deducer and explained, "This shows where we eat most—it showed that we ate at school most." Dario pointed to his drawing of the school that overlaid the computer-generated map and noted that many snacks showed up by the main gate of school campus. He also explained that the orange circle on his map marked where snacks were most concentrated in the lunch area of Midtown High. But Dario explained to me that he noticed a contradiction in the data. While the map suggested that most snacks were eaten on campus, the bar chart (Figure 8.19) showed that people reported eating at home the most. Dario pointed out that this was why he had written "How come two diffrent Answers/Datas."

Next, Dario moved on to explain his second poster (Figure 8.18) entitled "Snack cost/With who." Touching the bar graph that he had drawn with a thin marker, Dario explained that this graph showed how most snacks were under $1. This graph is shown below:
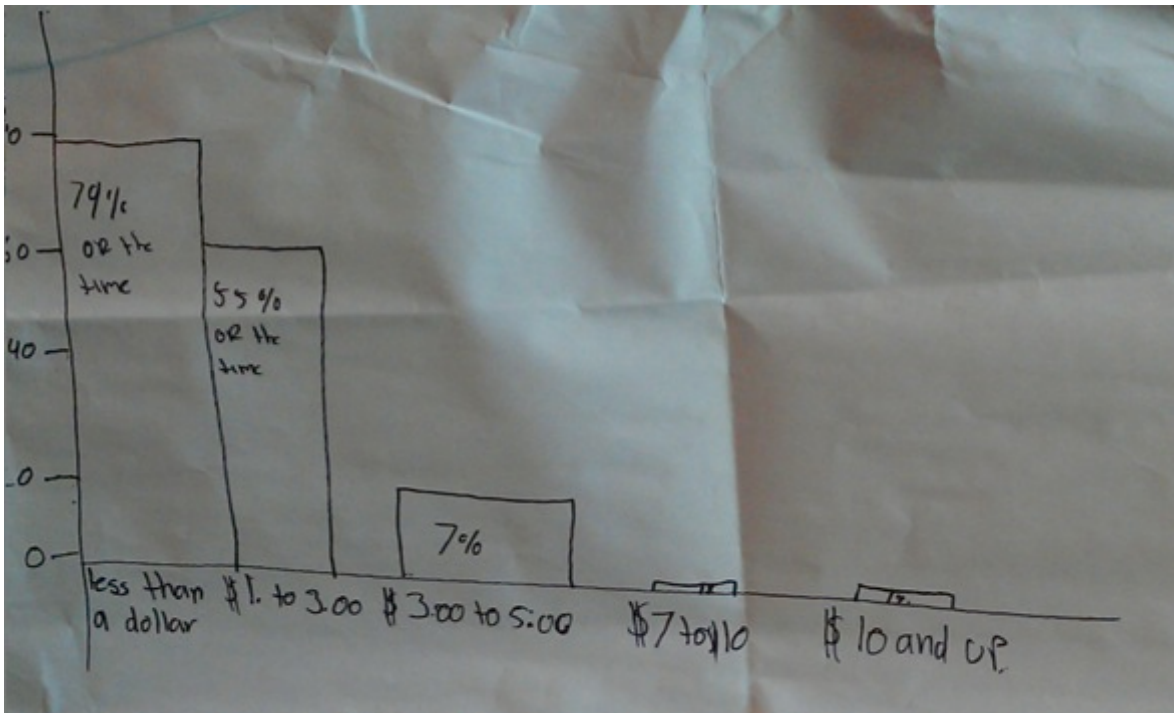
Figure 8.22: _Dario's bar plot depicting snack cost._

Reflecting on money spent on snacks, Dario pointed out that "snack cost depends on how much money the consumer has and how much he is willing to spend." Dario emphasized how teenagers wouldn't have that much money to spend or may not be willing to spend much on snacks. Then, pointing to the $10 and up snack, Dario laughed while explaining that this particular snack recorded in the data was his own snack, stating: "I was that 1% that was $10 and up because I ate a meal but di the survey for a meal that wasn't a snack." I thanked Dario for sharing his work with me.

While Dario did not appear to have spent much time on the aesthetics of his final project

posters (that included misspellings), important computer science practices still emerged from his

graphs and questions. Returning to the first poster describing where people ate their snacks

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(Figure 8.17), Dario was willing to challenge both the data and data representations that, in his opinion, seemed to contradict one another. This showed the computer science practice of "analyzing problems and artifacts." Dario pointed out how the map's emphasis on snacks appearing at school seemed to challenge his bar plots illustrating that most snacks were eaten at home. Of course, Dario did not go the next step further to consider how his classmates did not all live in the same house, let alone apartment building and, therefore, their snacks should not appear in a concentrated area as they would at the school. In other words, "home" on the bar plot of snack locations would not appear as a single place on the map of snack locations since students did not all live with one another. Furthermore, Dario made the error (on both posters) of marking the bars in his bar plots as percentages instead of total counts (e.g., the first black bar signifying people snacking at home in Figure 8.19 should be labeled "78 people" and not "78%"). Still, Dario's readiness to ask questions about the data and compare various data representations showed his growing critical thinking skills and emerging ability in the computer science practice of "communicating" the meaning of his results in context. Dario was willing to push his project further by questioning the representations of snack locations on his various plots on the first poster.

Dario's presentation of the second poster (Figure 8.18) also revealed deeper critical thinking skills and "communicating" computer science practices because he not only tried to interpret the snack costs in relation to students' real-life contexts—connecting his bar graph interpretation to the fact that students may not have much or any disposable income—but also reflected on his own snack data that created an outlier on the graph. Looking closely at the statements Dario made at the bottom of his "cost" poster, Dario's critical thinking skills surfaced in important ways:

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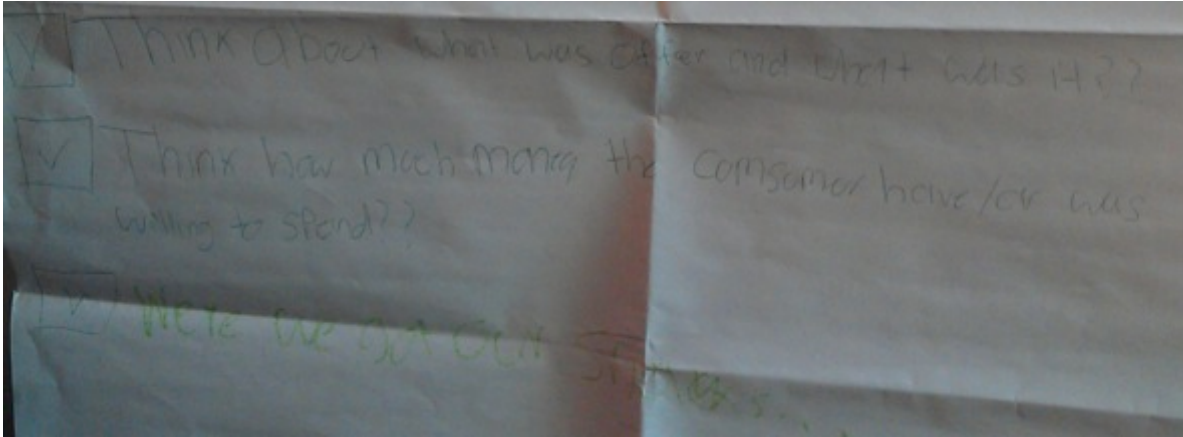
Figure 8.23: *Bottom statements on Dario's snack cost poster.*

Dario had written: "Think about what was offer and what was it?? Think how much money the comsumor have/or was willing to spend?? Were we got our snack??" Despite Dario's grammatical errors and misspellings, Dario was asking very important questions about the data in relation to cost, revealing careful critical thinking skills. In both his presentation and poster, Dario emphasized that "snack cost depends on how much money the consumer has and how much he is willing to spend." In this way, Dario was considering how the prevalence of snacks costing under $1 related to the cash readily available for students to spend. If one has more money, snack cost may increase but, as he pointed out during his presentation, teenagers rarely have much money and therefore wouldn't be willing to spend all their money on more expensive snacks. This recognition of students' real lives in relation to the bar graph showed how Dario was making important connections between the data and his analysis of the data and how he engaged the computer science practice of "analyzing problems and artifacts."

Dario's other two questions written on the bottom of his poster were also particularly interesting. Dario urged viewers to reflect on how the type and availability of snacks would affect students' snack cost data. If more expensive snacks were not available, then students wouldn't have spent their money on more expensive snacks. Similarly, Dario pointed out that the type of snack would also matter since it's possible one might spend more money on a snack one

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found more delicious, weighing taste against cost. Furthermore, Dario suggested that snack location might also impact snack cost. One might imagine how snacks at school may cost differently from snacks at a Metro stop.

While Dario's critical questions about snacking data in relation to his graphs were compelling, Dario could have made his project even stronger by displaying more computational artifacts and plots/graphs that would answer his questions about snack type, availability, or location. Still, Dario's questions revealed important critical thinking skills about factors affecting data collection and analysis processes. Dario's engagement of the computer science practice of "analyzing artifacts" (computer-generated plots/graphs) was typical of most projects in Ms. Mendoza's class.

Classroom Context for Dario's Learning – Ms. Mendoza Supports Critical Thinking

Considering that Dario's work was a typical example of an average final project in Ms. Mendoza's classroom, how did the teacher facilitate the development of computer science practices such as "connecting computing" and "analyzing problems and artifacts" that Dario demonstrated? How did Ms. Mendoza push students to consider their findings in relation to social context in the data analysis process? How did Ms. Mendoza support students in asking questions about the data and computational artifacts such as graphs and charts?

The influence of Ms. Mendoza's pedagogy on students' new skills in this research unit—made visible through Dario's final project—becomes apparent when returning to students' first exploration of their snacking data on May 1, 2012. On this day, students were introduced to the Web Front-End website where they could view their entire class's data and build simple bar charts, pie charts, scatter plots, word clouds, and maps. Ms. Mendoza asked students to work in groups to scan through their class data, play with the plot-building tools on the website, and

approach the data with open minds, stating: "Let's say you were scientists looking at this data. What would you say about it?" As students began playing with the data on the website, Ms. Mendoza walked around the room to different groups saying things like, "Make sure you're not looking at just pictures or types of food, but also things like location or time…" and "Okay group! What did you see?" The ways Ms. Mendoza supported students' critical thinking skills about their snacking data is revealed in the discussion that followed this activity as described in the vignette below:

After providing students with approximately twenty minutes to explore the data, Ms. Mendoza regrouped everyone and asked students to share their initial impressions. Saying, "Ladies first…" Ms. Mendoza called on Jesenia, Clara, Natalia, Jenny, and Bernice's group to state what they noticed first as she wrote their ideas on the board. Clara said, "Students from Metro City are eating not healthy snacks" to which Jenny explained, "they're eating mostly candy." Jesenia called out that students were eating "*reposados*." Ms. Mendoza turned to Lena's group and asked them to share some ideas as well, to which Lena replied, "Many students made unhealthy choices and ate snacks that are less than $3." Ms. Mendoza thanked Lena for looking beyond just food items to other variables while Mike added, "We also saw that most students are eating snacks at home or school." As Nico proceeded to reiterate that the majority of snacks were "unhealthy," Mike interrupted and asked, "What *is* healthy?" Ms. Mendoza responded: "Oooh! That's a really good question!" Then picking up an old fruit snacks wrapper out of the trashcan while jokingly saying, "Don't judge me! [for picking out of the trash]," Ms. Mendoza held up the wrapper and asked the class, "How many of you think it's healthy?" Students shared many ideas with Dario stating "It gets stuck in your stomach…" and Clara pointing out that it was unhealthy because "it's cheap." Ms. Mendoza replied, "Okay, so price. Why is it unhealthy?" Clara began to add "It has lots of sugar…" and Ms. Mendoza looked at the nutritional information on the wrapper and reported that there were 13 grams of sugar in a single serving and that the packet contained 2.5 servings. With a big smile, Ms. Mendoza said, "You do the math! It's like eating a can of soda! That's how much sugar is in it! It also has 19 grams of carbs! If I were diabetic, I'd have to be careful…" Then returning to Clara's comment about price, Ms. Mendoza asked what she meant by this, to which Xochitl called out, "healthy food is expensive, usually…" Then Anthony changed the subject, asking why so many snack entries in the student data were granola bars to which Samson explained, "That's the best thing at the student store!" after which Clara added, "The only healthy thing in the student store is water!" Ms. Mendoza said that this conversation was really interesting, but then returned to Xochitl's comment about cost in relation to healthy level, asking if she thought healthy meant expensive. Before Xochitl could respond, Dario pointed out "Cheesecake's expensive, but it's not healthy!" Ms. Mendoza replied "Good point!" as several students started laughing about how cheesecake could be made healthy. Ms. Mendoza then asked the class, "What else do you consider healthy?" Someone called out "natural" and Ms. Mendoza replied, "So no artificial ingredients…" as Xochitl added "or artificial flavors!" When Dario added that healthy could also refer to something "grown off the

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ground," Ms. Mendoza asked, "But corn is grown from the ground and corn starch comes from corn but is basically sugar…is that healthy?" Larry replied, "That's processed!" (M.FN.5.1.12)

This animated conversation based on students' snacking data describes one of the ways that Ms. Mendoza facilitated students' critical thinking and computer science practices ("connecting computing," "developing computational artifacts," "analyzing problems and artifacts," "communicating," and "collaborating") related to the data analysis process. As students shared their initial explorations of the snacking data, important questions surfaced about how to define "healthy." Building off this student-derived question, Ms. Mendoza proceeded to support students in developing their own understanding of healthy by asking probing questions. She would ask for their opinions, but then challenge their ideas in ways that modeled critical thinking. For example, when asking students about whether fruit snacks were healthy, she immediately asked students to explain their opinions. When Clara pointed out that the snacks had too much sugar, Ms. Mendoza did not simply agree or disagree, but modeled how one might confirm her statement by turning to the wrapper's nutritional information and reading aloud the fruit snack sugar and carbohydrate content. When Xochitl pointed out that healthy snacks were more expensive, Ms. Mendoza again asked her to explain this reasoning in a way that pushed more critical thinking about one's ideas. In the supportive learning community that Ms. Mendoza fostered, students like Dario or Clara were able to call out their ideas about how cheesecake was expensive but unhealthy or how the school store lacked healthy snacks. When Dario suggested healthy food was grown from the ground, Ms. Mendoza challenged this idea with a counter-opinion about cornstarch. Following Ms. Mendoza's critical analysis method, Larry then countered her statement by pointing out how cornstarch was different from corn because it was "processed."

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This discussion shows how Ms. Mendoza modeled computer science practices with data by ecnouraging students to think critically about their data in relation to definitions of healthy, access to healthy food, snack cost, or snack ingredients. Interestingly, these same critical questions—about snack cost, snack healthy level, snack availability, etc.—appeared in Dario's final presentation posters in new ways that also considered disposable income and snack location. Students' demonstrations of critical thinking skills and questions about their snacking data can be traced back to Ms. Mendoza's creative ways of supporting such practices in the classroom.

3. Sandra's Powerpoint – An Exemplary Project Revealing Important Data Analysis Skills

Sandra's powerpoint was one of the three top projects in Ms. Mendoza's class. Sandra's project included twenty-five slides describing: 1) two hypotheses about what she expected to find; 2) graphs (including two-variable plots) created to find out if her hypotheses were correct; 3) subsequent conclusions resulting from an analysis of these graphs; 4) questions that came up as she analyzed the graphs and addressed her hypotheses; 5) three extra graphs with additional analyses of note; 6) final thoughts garnered from conducting snacking research; and 7) suggestions for improving future research and ensuring that research findings affect positive social change.

An examination of the content of Sandra's first eight slides reveals impressive critical thinking, data analysis skills, and computer science practices. These are shown below:

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a.

b.

c.

d.

e.

f.

g.

h.

Figures 8.24a-h: *Sandra's first eight slides of her final project powerpoint (with real names of city, school, program, etc. blocked out to protect privacy).*

As visible in Figure 8.24a, Sandra's initial hypothesis was that "my predictions were that the healthy level would be affected by the snack location." Sandra makes it clear that she based this off of her initial engagement with student snacking data on the Web Front-End, demonstrating the computer science practice of "connecting computing." In an effort to find out if her hypothesis was correct, she then proceeded to analyze the snacking data by building several computational artifacts visible in these graphs shown in her powerpoint: 1) a bar plot showing the distribution of snacks in each healthy level; 2) a bar plot showing where snacks were eaten; 3) a box plot with healthy level on the x-axis and snack location on the y-axis; and 4) a scatter plot with healthy level on the x-axis and snack location on the y-axis. On the slides in Figures 8.24f and g, Sandra explained that these graphs "facilitated" her understanding about the "accuracy" of her hypothesis, noting that the graphs show that most snacks were eaten at home and school with the most unhealthy snacks eaten at these locations. Demonstrating the computer science practice of "analyzing artifacts," Sandra explained that only 20% of snacks eaten at home and school were healthy. While Sandra did not clarify which graphs led her to these conclusions, her interpretation was quite accurate. The graphs did show that most snacks were eaten at either home or school. Furthermore, the graphs also illustrated that few snacks eaten at

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home or school were labeled "5" or "Very Healthy," as the median healthy levels for snacks at home and school were a "3" according to Sandra's box plot in Figure 8.24d and the majority of points for home and school on the scatterplot in Figure 8.24e were measured at a healthy level of "3" or lower, signifying middle-range to unhealthy food.

Interestingly, when reviewing Sandra's presentation of this powerpoint, it appeared that she was uncertain about how to read her graphs. This uncertainty may have been brought on by nervousness when presenting in front of the camera (Sandra kept moving her gaze while always avoiding eye-contact with the camera, she kept playing with her hair—pulling it back, brushing it behind her ears, pressing her bangs/fringe away from her eyes, etc.—while leaning her body toward and away from the computer, she kept swinging her upper-body weight from left to right arm, and she kept shifting her lower-body weight from left to right knee while half resting on a chair in front of her computer).

When presenting her powerpoint to me on June 8, 2012, it seemed as if Sandra had forgotten the order of her slides. It took her a while to explain the individual graphs on demand. Clicking through her powerpoint slides, when she arrived at her first graph—the bar plot of healthy levels (Figure 8.24b)—she said, "Here are the graphs…These are, um…" Sandra had to pause an entire second and lean in toward the computer to make sure she knew what graph she was interpreting, then stated, "…like, the percentages of the healthy levels overall," then while shifting her gaze toward me she added, "…or that were entered." Sandra continued to the next slide (Figure 8.24c), leaning toward her computer again to interpret this bar plot of snack locations and said slowly, "Um…then…" Then, while picking up her pace she added, "…where they ate the most snacks…is all…at home and school." Sandra's real discomfort with discussing her plots became evident when she quickly passed over the next slide (Figure 8.24d) that showed

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a boxplot of healthy levels vs. snack locations. Then, looking at the scatterplot on the next slide (Figure 8.24e), Sandra said slowly, "And then…" while nervously circling her thumb over the bottom right corner of the screen. Finally, she added, "This graph shows, uh…most of the snacks ate…?" Sandra's vocal pitch rose at the end of this statement, making her description of the slide sound more like a question. Sandra continued to pause while pulling her hair back and leaning even closer to her computer. Without explaining the box or scatterplots, Sandra switched to her "Conclusion 1" slide (Figure 8.24f) while saying, "Hold on, here it is…uuuummmm…" Then after silently and quickly reading this slide, she passed on to the second of her conclusion slides (Figure 8.24g). Straightening herself upright, Sandra brushed her hair behind her ear, switched her weight from left to right knee on the chair, and summarized her conclusion while stating, "So the graph show that the locations where the most snacks are eaten are at home and at school but those are also the locations where the most unhealthy snacks are eaten…according to the graphs only 20% of the…[shifting her gaze back to the computer] uh, snacks eaten [shifting her gaze to the back of the room then to me] at home and school are healthy. And the rest are unhealthy." Sandra ended her statement with a nervous laugh, cocking her head toward me and smiling while gazing at me through the upper corners of her eyes. Then she offered to show me her graphs again.

When I asked Sandra to explain the scatterplot, she looked nervously to the back of the room, sighed, and then said, "I think it's the wrong graph…" but then continued by saying, "Like this is the relation with health level and snack location…It's the graph that mixes it up." In an effort to check Sandra's understanding and see if she really comprehended her own project (since she seemed uncertain about her graphs), I proceeded to ask her to explain the meaning of healthy levels "1" vs. "5" and then asked with the intonation of a statement, "So you're saying that

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there's more healthy snacks at home than at school?" This was *not* what Sandra had told me, but I was checking to see if she would notice my error. She paused, considering my question, and said firmly while standing upright and looking me in the eye, "No. I'm saying both at home and at school are unhealthy." At this point, Sandra's discomfort with presenting seemed to melt away and she took charge of her ideas as visible in the increased speed of her speech (as if she was sure of her words), her more relaxed posture toward me, and her calm gaze. She proceeded to say, "Yeah, So I thought my hypothesis was wrong 'cause I thought it's, like, at home it would be healthier…" and I interrupted to show my understanding, saying, "Oh, but you felt like there was no difference?" to which Sandra replied, "Yeah, it's not, there's no real difference."

Following this statement, Sandra's deeper critical thinking skills and confidence with her project really began to surface as she demonstrated the computer science practices of "connecting computing," "analyzing artifacts," and "communicating." While she seemed uncertain (but not incorrect) about her on-the-spot interpretations of the box or scatterplots, Sandra demonstrated a compelling ability to consider issues related to both data collection and the implications of her analyses. Moving to her "To think About" slide (Figure 8.24h), Sandra noted, "there are some things to think about: How accurate are the healthy levels really? Like, for each person, everyone has a different idea of what healthy means. So we don't now if, for, like Annie, chips are like a '5' or a '1,' you know? So it all depends. I think that [MyData] should have given a chart saying what falls under what category, like under which number. So here [pointing to her slide] there are some things to think about, you know? Like, to see how accurate the data really is and how much it really helps research." Sandra said these ideas very fluidly, reflecting her careful thoughts about how we cannot be certain of the actual healthiness of students' snacks since we cannot confirm how students defined healthy vs. unhealthy.

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Furthermore, not only did she question the accuracy of the data, but she demonstrated important creative thinking when suggesting a solution to this problem by noting that survey-takers could be given definitions for which snacks should be labeled healthy vs. unhealthy.

At this point, Sandra looked toward her slide again, gathering her thoughts for a brief second before going on to tell me, "Also, I don't think there was enough time to really gather the information. Like, if we had had more time…" I nodded my head in agreement and Sandra decided to move on to her next hypothesis. Again, this section of her presentation on video showed that Sandra was carefully considering how research conclusions would be impacted by variations in survey-taker's opinion as well as the amount of data available for analysis. Sandra's ability to consider data source, context, and impact on final conclusions was an important data analysis skill and computer science practice.

Returning to her presentation, Sandra shared her next hypothesis, graphs, and conclusions in her powerpoint as shown below:

a. *b.*

c. *d.*

e.

Figure 8.25a-e: *Sandra's next five slides depicting her second hypothesis and conclusions.*

As visible in these slides, Sandra initially thought that "who you snack with has an impact on the type of snack you chose" (Figure 8.25a). Interestingly, unlike her presentation of the first hypothesis, when explaining the subsequent graphs she created to test her hypothesis, Sandra gave me more detailed interpretations of the plot slides (Figures 8.24b and c). Showing a new

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effort to explain her data analysis process during her presentation to me, Sandra actually sat down in a chair and talked about the bar plot in Figure 8.24b for a full twenty-three seconds—much longer than she had discussed any of her other plots. She explained that this bar plot showed the "amounts of time students who participated in the research snacked alone, with family, and friends." Then gesturing with her left hand at the two largest bars on the graph, she noted, "and clearly you can see that these two graphs [bars] are the biggest ones. So there's like 40% that snacked alone and 50% that snacked with family, so that's pretty important." While, like Dario above, Sandra incorrectly stated that the bars represented percentages and not numbers of people, her general point was correct that most snackers ate with family or friends. Then, Sandra moved on to the next slide showing a word cloud (Figure 8.24c) and correctly described what it meant saying, "And here the bigger words were the ones that were most popular among the students." Sandra's willingness to sit down and spend more time describing these plots revealed her increased comfort with both presenting and explaining her slides while demonstrating the computer science practices of "analyzing artifacts" and "communicating in context."

Sandra's excellent computer science practice of "analyzing artifacts" and her data analysis skills became evident as she explained her conclusions from these graphs. Clicking forward to the slide in Figure 8.24d above, Sandra read over her points silently, gave a sighing laugh, then stood up to say to me, "Okay, there was no real conclusion drawn in this between those two factors because the information was pretty even in the data, like there was no real difference in the health level and the type of snack you eat with, who you are [shaking her head] there's really no differential in the data. So I couldn't really come to a conclusion about my hypothesis."

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Indeed, Sandra was correct in noting that she couldn't come to a conclusion about whether snacks differed depending on who they were eaten with since the word cloud did not specify *who* snacks were eaten with. Of course, this question could have been answered if Sandra had created subsets of the variable "who you snack with" (therefore creating separate subsets for the "family" category, "friend" category, etc.) and then building separate word clouds for each subset and comparing them. However, it is not surprising that Sandra failed to build subsets and compare word clouds because Ms. Mendoza never taught her students how to do this. Thus, Sandra went as far as possible with the skills she was taught.

What was particularly compelling was Sandra's "to think about" slide (Figure 8.24e) showing Sandra's more advanced applications of these research efforts to community chang, revealing the computer science practice of "connecting computing." While presenting to me, she told me that she came up with the question, "How can the image with the bigger words and the smaller words, how can it be used to maybe help or get a plan to change health, like eating habits after the research?" Gazing straight into my eyes, Sandra said, "Like maybe, if we look at the big words, the healthier bigger words we could maybe start campaigns with these type of snacks rather than others because they're bigger and so they're more popular among people." Sandra makes an important recognition about the implications of data on the community by suggesting how the word cloud computational artifact could be effectively used.

While most students would have ended their project at this point, Sandra's powerpoint included three more plots, including a scatterplot comparing snack cost (x-axis) to healthy level (y-axis), a word cloud showing reasons why people snacked, and a map depicting the high number of snacks eaten at the school's location. After glossing over these slides in her

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presentation, Sandra's data analysis skills began to shine again through the ideas she shared in her final slides:

a.

b.

c.

d.

e.

Figure 8.26a-e: _Sandra's final slides describing implications and plans for future action (with real names of city, school, program, etc. blocked out to protect privacy)._

First of all, Sandra made an important point about the research sample size. As visible in the second point on Figure 8.26a, Sandra noted, "Even though the data is not as accurate as wished, blending [Midtown High] data with the other schools data who also took part in the research,

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will give the researchers a broad spectrum to draw conclusions from and ideas as well." This suggestion shows Sandra's ability to understand that more data points results in more accurate interpretations. She expanded on this idea in the slide visible in Figure 8.26d, where she stated, "However, I do think that for the research to gain more accuracy, the time frame in which the data is being entered should be extended. Letting the data get bigger helps the categories get smaller and the information to be clearer. Also, more schools should be included." These are very important ideas in data analysis and research, showing that Sandra learned important concepts about how to get more accurate results. The statement that more data "helps the categories get smaller and the information to be clearer" is particularly interesting because it shows how Sandra understood that each data point carries too much weight when there are two few of them. When there are more data points, greater generalizations may be made. Sandra emphasized this during her in-person presentation as well by saying, "I think that for the data to really be helpful, we need to mix in all the data from all the different schools…so we have a wider understanding…"

Furthermore, Sandra demonstrated her ability to focus in on specific variables for making sense of health trends in student snacking by pointing out which data would be most illuminating for further research. This reflected the computer science practice of "analyzing artifacts" and ata. She pointed out (Figure 8.26.b) that "healthy levels of snacks, who the person snacked with and location in which the snack was eaten" would reveal the most about health-related issues in snack consumption.

Moving beyond just the research to consider why that research would be important, Sandra also reflected computer science practices of "connecting computing" when saying in her next bullet-point on the same slide (Figure 8.26b): "In my opinion, these three factors are the

most important to figure out an action plan and start changing bad habits as fast as possible."

Like a professional computer scientist, Sandra was seeing how computing could impact society y describing how this data could be used in its social context. This particular research skill and computer science practice became even more evident on the next slide (Figure 8.26c) where she stated some suggestions for improving snack health. She wrote:

- A long term solution would be to approach parents and inform families about the importance of a healthy lifestyle and specially the difference good eating habits can make throughout ones lives. Advertisement from the governments and private companies with healthy products should be put up advising people on better food choices. This plan should definitely be taken into consideration, and put under action, however, a short term solution would most likely happen on school grounds.
- Getting this data to government authorities and proposing a change in the school menu would be an option. Another option would be to incorporate more physical activity in school such as dance clubs and providing the students with health talks and healthier snacks afterwards. Including physical fitness in the path of achieving good health is important since healthy eating habits and exercise go hang by hand. You can't combat bad health if your missing one or the other.

While Sandra made some grammatical and spelling errors, her main ideas presented in this slide show her own creativity in relating research to community action. While her view of the positive role that government and private companies can play in improving community health may be idealistic—assuming that both government and private companies put peoples' health before corporate profit—Sandra's suggestions for ways to make positive change showed her interest in civic engagement in relation to this snacking research in her computer science class. Sandra made important connections between academic data analysis, the creation of computational artifacts through graphs, and community change.

Classroom Context for Sandra's Learning – Supporting Independent Thinking

How was Sandra able to develop her computer science practices and critical data analysis skills through this project? As visible in the vignette previously shared under Dario's project example that described how Ms. Mendoza encouraged critical thinking, Sandra's willingness to

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question her data and research most likely grew out of the ways Ms. Mendoza facilitated this

approach to learning. However, Ms. Mendoza also supported students to think independently and

pursue their own questions on a regular basis in ways that facilitated the kind of critical thinking

Sandra demonstrated in her final project. Consider the following vignette from May 25, 2012.

On this particular day, Ms. Mendoza had separated her students into two groups, each re-

categorizing different sections of the student data to simplify the entries in those sections. For

example, one group had re-categorized "type of snack" so that entries including "Doritos,"

"Cheetos," and "chips" would all be categorized under the same label of "chips." After giving

students time to do this, she began to suggest how students in the separate groups would share

their new files with each other, but Sandra had come up with what she believed to be a more

efficient way of sharing files. Instead of simply refusing Sandra's suggestion, Ms. Mendoza

asked her to clarify her approach and try it out with a classmate. This is described below:

Ms. Mendoza stood up on a chair and announced, "I'm going to stand on this chair for added dramatic value! Okay, this side of the room [and she swept her arm toward Sandra's side of the room] should have two files open. Now, combine the snack data and go…" but then Sandra interrupted her and asked, "What's the point? Why don't we all do it since it's going to be the same thing? Half of the list they do it and half of the list we do it…we don't have to do it two times…" Ms. Mendoza wasn't quite following what Sandra was saying and said tentatively, "Yes, that's what we're doing. Since you don't have 'why snack,' you did 'what snack.' Then you take what they did and then…does that make sense?" Sandra replied in a questioning voice, "yes…?" and Ms. Mendoza asked her in a kind voice, "did I understand what you were saying?" Sandra replied, "No." Both were smiling but not quite understanding each other, so Ms. Mendoza asked Bernice—who was in the 'why snack' group—to pair up with Sandra and try out Sandra's method. She said "Bernice, Sandra has a faster way of doing things so we're going to see if it works…" Sandra began to wave down her own idea, trying to stop Ms. Mendoza, but Ms. Mendoza urged Sandra to move next to Bernice and try her method while the rest of the class did Ms. Mendoza's method for combining the edited data files.
After about five minutes, Ms. Mendoza checked in with Sandra and Bernice. Sandra said that she had been wrong and she told Ms. Mendoza, "my idea was stupid because it wasn't any different than yours!" Ms. Mendoza smiled and replied, "At least you came up with something [on your own] versus the teacher telling you, 'No it's not going to work!'" Sandra asked, "Me?" and Ms. Mendoza responded with a smile, "yes you!" (M.FN.5.25.12)

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As demonstrated above, when students like Sandra came up with their own ideas about how to proceed through an activity, Ms. Mendoza would ask them to explain their thinking without stopping them from trying out their different ideas. While some teachers may have responded to Sandra's alternative file-sharing suggestion with disdain or simply ignored it, Ms. Mendoza encouraged Sandra to try out her own way of file-sharing with a classmate. Even when Sandra showed a moment of insecurity, waving away Ms. Mendoza's suggestion that she try out her own method, Ms. Mendoza still encouraged Sandra to pursue her own ideas. Ms. Mendoza's effort to support students' individual and creative ways of thinking were further emphasized when she told Sandra that at least there wasn't a teacher in the room shutting her down and telling her "it's not going to work."

If Ms. Mendoza had not encouraged independent thinking in her classroom, it is possible that Sandra would not have explored the implications of her data as creatively as she had in her final project. With a teacher pushing her to pursue her own ideas, Sandra was able to blossom as a creative computer scientist and critical thinker in her data analysis project.

City High School Final Projects

At City High, twenty-eight total students borrowed phones and participated in data collection. Students without phones still participated in data analysis and created final projects using their classmates' data. Of the twenty-eight participating students, fifteen completed projects—some individually and some collaboratively. There were eleven completed projects submitted to the teacher, including six Scratch animations, three powerpoints, one webpage, and one webpage with embedded Scratch game. One of the Scratch animations was created collectively by Ruby, Maura, Lisa, and Darrel, and another was the result of a collaboration between Eddie and Jaime. These projects are tabulated below:

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Figure 8.27: City High School overview of final projects.

Total # of Participating Students	Total # of Projects	Powerpoint	Website	Scratch Animations	Website + Scratch Game
28	11	3	1	6	1

The complexity of City High students' data representations (in the form of graphs constructed through the JGR/Deducer data analysis program) varied in these final projects. Six projects included only one or even no plots/graphs. Five projects included two ore more plots/graphs. Most plots/graphs displayed in City High students' projects involved only single variables. Only two projects included a two-variable plot. Furthermore, none of the students created subsets of the data, however one student (James) actually "pre-processed" his data before graphing it. In his final project (described in greater detail below), James created a bar graph depicting why people snack. Since this survey question was open-ended, most students survey responses included full sentences such as "I was hungry." Recognizing that words such as "I" or "was" would not be useful in a bar graph describing why people eat snacks, James figured out how to pre-process his data set so that all articles (a, an, the) and pronouns (I, we, etc.) were removed from the graph. This created a more legible and useful bar graph. This pre-processed data bar graph was the most advanced data representation I saw in all of the three classrooms. The variation in City High students' final project graph/plot complexity is shown in the table below:

Figure 8.28: City High School plot/graph complexity.

# of plots/graphs	0 plots	1 plot	2 plots	3 plots	4 plots	5 plots
# of projects	2	4	1	2	1	1
# of projects containing 2-variable plots	0	0	1	0	0	1
# of projects including sub-setting or pre-processing of data	0	0	0	0	0	1

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Coding of these projects revealed that most students provided primarily surface or incorrect interpretations of their graphs. For example, Peter created a Scratch animation project that resembled a public service announcement. In this animation, Peter had a Tinkerbell fairy character convince a breakdancing boy that he should eat healthy snacks and exercise in order not to get overweight like Ronald McDonald (who, according to the animation, is no longer seen in commercials because he gained too much weight from eating unhealthy snacks). Peter displayed only one plot: a single-variable pie chart showing why people snack from his classmates' data. This is shown in the animation scenes below:

a.   b.

Figures 8.29a and b: *Scenes from Peter's animation project (with real names of city, school, program, etc. blocked out to protect privacy).*

As visible in Tinkerbell's statements about the pie chart above, Peter's only interpretation of this chart was that "people eat because they they felt like it and not for any benefits." This interpretation seems weak because Peter was assuming that students' reasons for snacking—including reasons such as "For energy" or "Had no lunch" or "Hungry" that are written to the right of the pie chart—were not beneficial reasons for eating a snack. One could argue, however, that these were very important reasons why people *should* eat food. Peter's statement that students did not eat "for any benefits" seems unfounded in the data. Furthermore, Peter did not clarify what colors on the pie chart were most prominent and, thus, which reasons were most

important for students' snacking choices. In other words, Peter did not actually take the time to interpret the meaning of this pie chart.

Some students' projects were also weak due to the inclusion of graphs that lacked appropriate labeling and explanation. Consider, for example, a bar plot Carlos included at the end of his Scratch animation below:
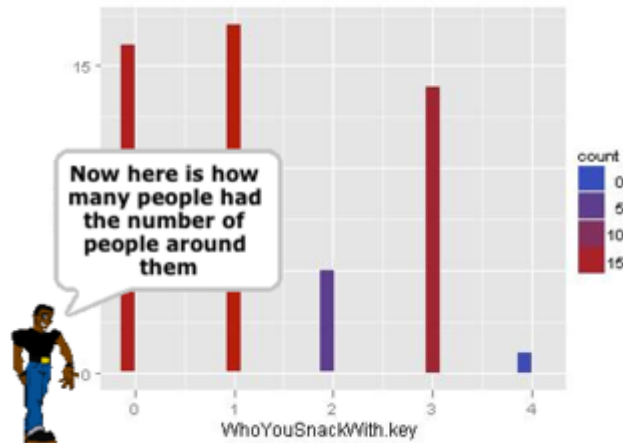
Figure 8.30: *Scene with a bar plot from Carlos's final presentation animation.*

While the bar plot notes "WhoYouSnackWith.key" along the x-axis at the bottom of the bar plot, it is unclear what this bar plot is actually depicting. The colors refer to a total count of something (represented in the plot key to the right of the graph), but there are no labels explaining what each color represents. Furthermore, the labels along the x-axis are the numbers 0-4, with no clarification about what these numbers mean. It appeared that Carlos did not know what they meant either, because his animation character proceeded to say "Now here is how many people had the number of people around them." This circular comment did not seem to explain exactly what this graph was depicting and how it was useful to Carlos's data analysis.

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Still, while Carlos failed to offer a strong or even clear analysis of this particular bar plot in Figure 8.30, a previous scene did show a correct description of a word cloud:

Figure 8.31: *Word cloud analysis in Carlos's animation.*

Carlos demonstrated his understanding about how to analyze the word cloud in Figure 8.31. However, Carlos did not dig deeper into his analysis of what students ate based off of this plot. This type of surface-analysis of simple, single-variable plots/graphs was typical of students at City High.

Three pieces of student work representing a typical weak, typical average, and typical above average final project are analyzed in greater detail below.

A Closer Analysis of Three City High Final Projects

1. Jaime and Eddie – A Focus on Looks over Content

Jaime and Eddie teamed together to create both a website and Scratch computer game for their final project. Both students dedicated a lot of time to creating an eye-catching website that included a yellow moving copyright banner stating, "Students buy snacks™ 2011-12 by Sw8.

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All Rights Reserved" at the bottom of the page, an animated image of a popular cartoon character ("Patrick" from *Sponge Bob* who was visible eating a hamburger on the bottom left panel), a research conclusion that typed itself out into a paragraph in the middle of the page (animated black text), and a Scratch game that was supposed to be embedded at the top of the page (where the website says "missing plugin") but that did not embed properly during their final presentation. On the day of their final presentation, Eddie and Jaime troubleshot this situation by adding a hyperlink to a separate website containing their game (the hyperlink is in purple and states, "learn more about this project"). A still image of their website is visible below:
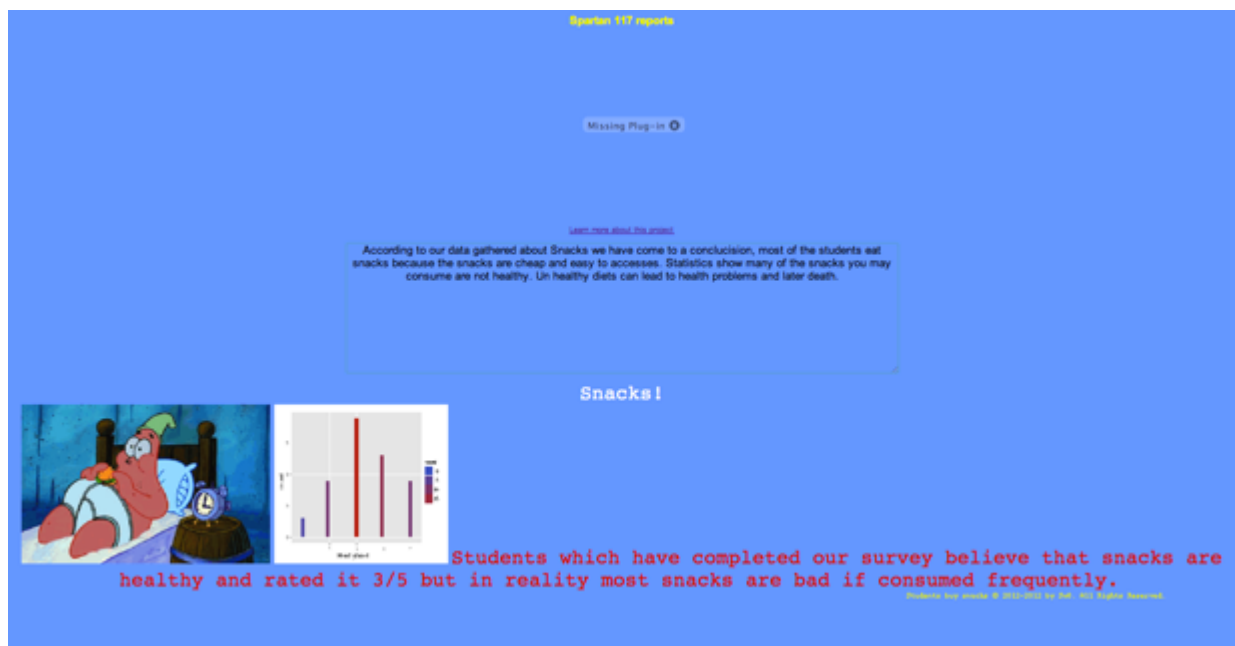
Figure 8.32: *Jaime and Eddie's final project website.*

The top of Jaime and Eddie's website states "Spartan 117 reports." This is a reference to the protagonist named "Spartan 117" in the *Halo* game series. This gaming character was the last remaining super human on which humankind depended for survival. The students jokingly identified themselves as "Spartan 117" reporting on their class research findings. The black text that typed itself across the center of the website stated:

www.manaraa.com

According to our data gathered about Snacks we have come to a conclucision, most of the students eat snacks because the snacks are cheap and easy to accesses. Statistics show many of the snacks you may consume are not healthy. Un healthy diets can lead to health problems and later death.

The red text at the bottom of the website page to the right of the students' bar graph provided an analysis of this graph, explaining: "Students which have completed our survey believe that snacks are healthy and rated it 3/5 but in reality most snacks are bad if consumed frequently."

The graph showed the total number of snacks in every healthy level as visible below:
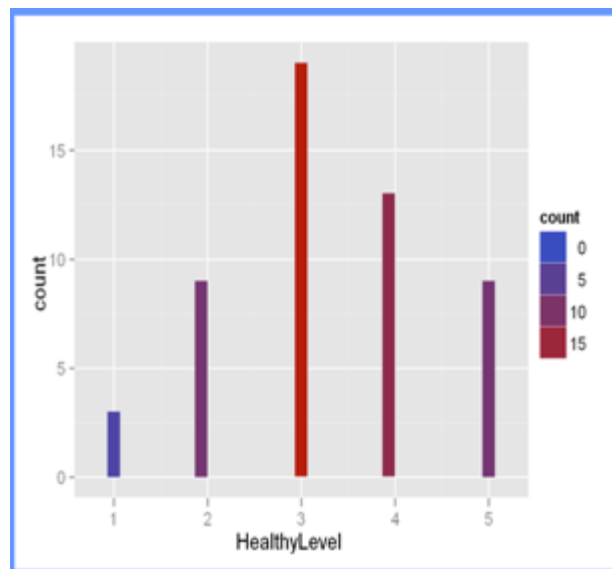
Figure 8.33: *Bar graph detail from Jaime and Eddie's website.*

The Scratch game that the students created (as accessible from the hyperlink embedded on their website) involved a skinny boy character who the game-player had to move around the screen in an effort to avoid a moving cloud of unhealthy snacks. Whenever the boy character touched the snack cloud, he would balloon up into an overweight version of himself and the "weight" count in the top left corner would skyrocket. Some stills of this computer game are visible below:

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a.   b.
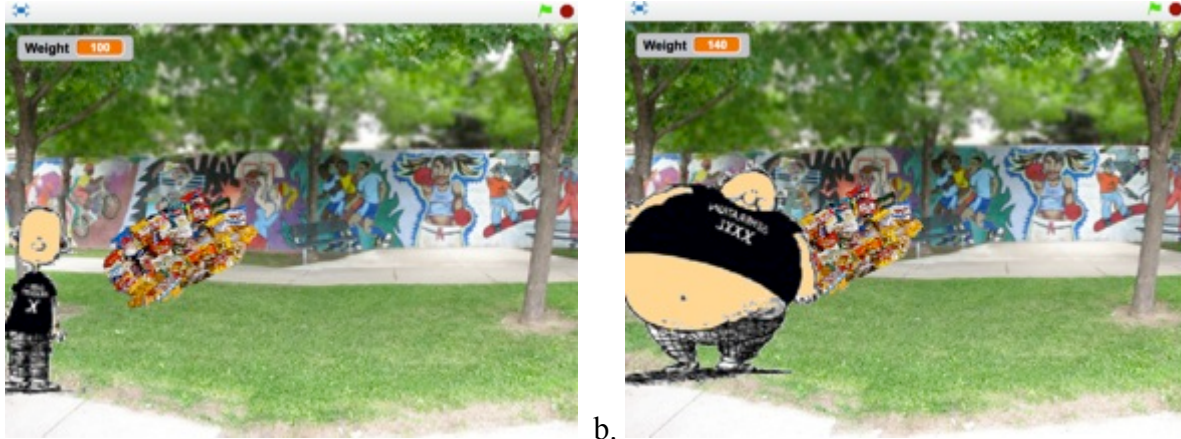
Figure 8.34a-b: *Still frames from Eddie and Jaime's Scratch computer game. To the left, the skinny boy stands calmly, but it is the game-player's objective to avoid the cloud of snacks that are moving toward him (visible to the right of the boy in the image). The boy's weight in Figure 8.34a is 100. Figure 8.34b depicts what happens when the boy touches the cloud of unhealthy snacks. His body balloons up to an overweight image of himself and his weight increases to 140.*

As evident in both the additional images and animations that Jaime and Eddie included in their website, as well as the details of their Scratch game, both students used their creativity and computer science skills in html and Scratch programming to develop visually stimulating computational artifacts. The typing, scrolling, animated cartoon character, hyperlink, etc. of the website revealed strong skills in html programming that the boys had learned earlier during the school year. Importantly, neither student had ever made a website before enrolling in Mr. Santos's class. Furthermore, Jaime and Eddie's Scratch animation game (also new to these students during this school year) demonstrated their innovative sense of humor when creating an interactive aspect to their final project. This game project (jokingly entitled "Phat," which can be interpreted as meaning "Cool" or "Awesome" while obviously also sounding like the word "fat" in reference to the dangers of touching the snack cloud) involved complicated programming skills. These two students had to program the game-players' movements so that the game character would move according to arrow keystrokes (see blue blocks in programming script below, Figure 8.35). Furthermore, they made sure that the character would face the direction of

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his movement (e.g., facing left when moving left according to the game-player's keyboard strokes). Also, the boys incorporated code that ensured the game character would become an oversized version of himself when touching the cloud of snacks (see turquoise "touching" blocks). In addition to changing the look of the boy, the students included a variable (entitled "Weight"—see orange blocks) that would increase by 10 whenever the boy character was touched by the snack cloud, but that would return to 100 whenever not touching the snack cloud. These programming choices are shown below:

Figure 8.35: *Programming script used by Jaime and Eddie to create their "Phat" game.*

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It is clear that Jaime and Eddie engaged important computational thinking skills relevant to computer science when both building their html website and designing this Scratch game. This became even more apparent when Jaime and Eddie realized that their game wouldn't load on their website, and so, on the spot, they inserted a hyperlink that made their game accessible on a different website. The students were able to think quickly on their feet and figure out a way to troubleshoot the situation just before presenting their project to the class. The boys showed their abilities to excel with the computer science programming tools they were introduced to during the 2011-12 school year.

However, this project represents one of the typical "weak" projects of Mr. Santos's classroom because Jaime and Eddie offered only a surface-level interpretation of the single-variable bar plot they included on their website. The only analysis these students provided was that snacks measuring a "3" healthy level were the most common in their class. Jaime and Eddie could have gone deeper with their interpretation to also note that snacks labeled 4-5 outnumbered snacks labeled 1-2. Or, similar to students at Midtown High, Jaime and Eddie could have questioned the potential variability in health judgments used by students when labeling their snacks as 1-5 healthy level. However, the boys did not push their interpretation further in this way. Also, at the center of their website, they made the conclusion that students eat snacks that are "cheap and easy to accesses." Yet, they did not include graphs depicting whether or not this was true and failed to support their findings. Their comment about "statistics" was unsupported by either citations or data.

When viewing video footage of Jaime and Eddie presenting their website to classmates and teacher (on May 14, 2012), the boys added little else to the information provided on their website. When showing the graph and the website, they simply read off of the text included on

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the page, adding no other analyses. When presenting their Scratch game, they noted that it had an educational purpose as Jaime explained "we created a game as well just to show you a picture of what could happen if you eat too much snacks" but this did not build off of the class data or research. Jaime and Eddie saw an important, real life connotation for their game as Jaime explained to his classmates and teacher: "'Cause I was thinking, in real life, you know, they're trying to *get* you to eat it, so you gotta avoid that. So just like you gotta avoid eating junk food." While this idea was compelling as an impetus for creating the game, it still was unrelated to the data collected and analyzed for this project. This surface-level/unfounded interpretation of class snacking data represented some of the weaker computer science and data analysis practices at City High.

2. Olimpia's Powerpoint – Emerging Critical Thinking Skills with Surface Data Analysis

While Olimpia never presented her final project to her class, she completed a powerpoint that showed developing abilities to think critically about data and research processes and the computer science practice of "analyzing artifacts." In contrast to many other projects, Olimpia's project presented student data in a more creative way by showing both individual snack entries as well as trends in snacking data. Using photograph data collected by students—which only two other students in her class also included—Olimpia's first two slides noted that students' snacks could be considered unhealthy and tended to be cheap:

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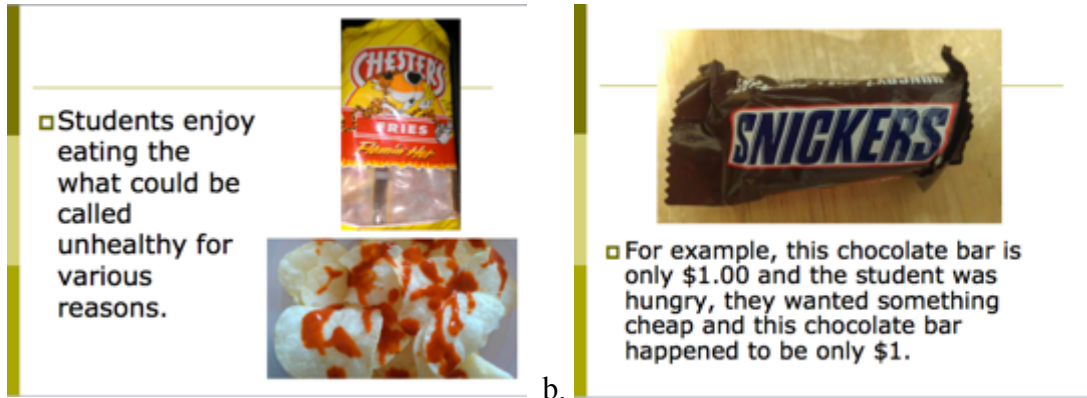
Figures 8.36a-b: _The opening slides for Olimpia's powerpoint project._

While Olimpia did not explain why these snacks could be considered "unhealthy," it was compelling that she introduced project viewers to real photos from student snacking data as well as a summary of one specific snack entry. She then proceeded to share trends in the data, offering straightforward analyses of various graphs and plots. For example, in the bar plot below depicting healthy levels for all snack entries, Olimpia correctly interpreted that students mainly ate snacks measuring a "3" on the healthy level scale:
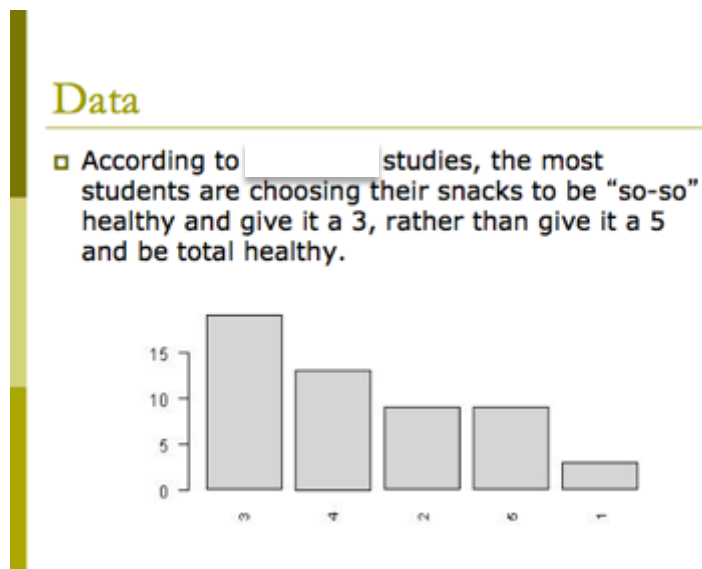
Figure 8.37: _Olimpia's bar plot showing student snack healthy levels (with real names of city, school, program, etc. blocked out to protect privacy)._

Of course, this slide was neither exciting nor surprising. It represented an average project in Mr. Santos's class, giving surface interpretations of data representations. Yet Olimpia's deeper thinking skills began to emerge in the slides that followed. In subsequent slides, Olimpia shared graphs and plots with accurate surface-level interpretations *as well as* suggestions for *why* students' snacking results appeared as they did. Her tentative assertions about the data show emerging computer science practices of "connecting computing" and "analyzing artifacts" by reflecting on the social context of her computational artifacts (the graphs/plots). Consider the two powerpoint slides below:

a.   b.
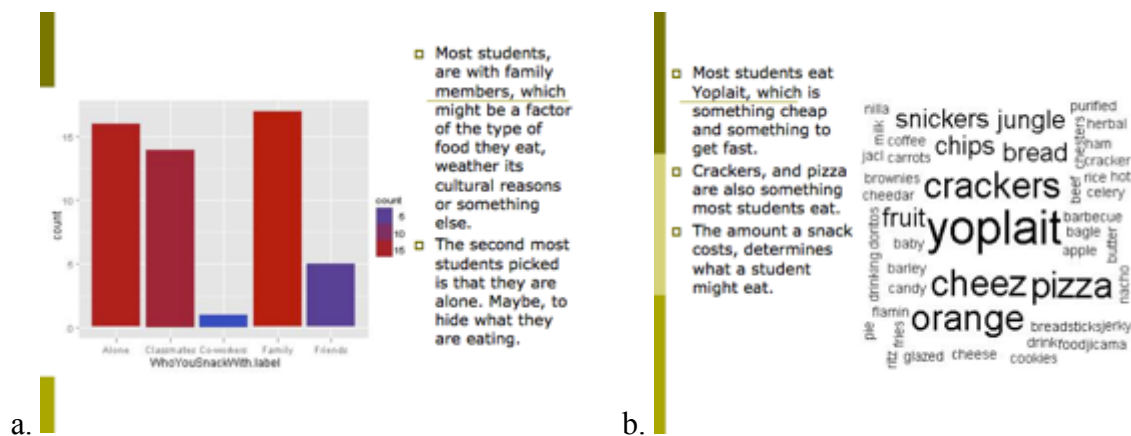
Figure 8.38a-b: *Two deeper thinking slides from Olimpia's powerpoint.*

As visible in Figure 8.38a, Olimpia provided a bar plot showing who people snacked with. She correctly noted, "Most students, are with family members…The second most students picked is that they are alone." While these interpretations were simple, Olimpia's suggestions for why students ate with family or alone showed some deeper thinking skills with data analysis. She noted how eating with family "might" be common due to "cultural reasons." Her use of the word "might" suggests that Olimpia was sensitive to the fact that her conclusion about cultural influences on snacking behavior was not proven by the graph and only reflected *one* of many possible interpretations of this trend. Similarly, when reflecting on why people might have been snacking alone, Olimpia noted "Maybe, to hide what they are eating." Again, her use of tentative

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language while attempting to analyze *why* students snacked alone showed Olimpia's budding skills as a data analyst who reflects on the sociocultural context. She demonstrated these same skills in the next slide depicting a word cloud of what students eat (Figure 8.38b). Here she correctly noted that the most common snacks (the largest words in the cloud) were things like Yoplait yogurt, crackers, or pizza. Reflecting on the demographic of students collecting this snacking data, Olimpia explained that, "The amount a snack costs, determines what a student might eat." She could have gone deeper with this idea by also displaying graphs of snack cost in relation to snack item as a means of proving the idea that cost might determine what a student eats, however her effort to consider why snacks like Yoplait, crackers, or pizza would be common among students reflects a growing analytical sensibility. Olimpia demonstrated budding computer science practices related to "connected computing," "developing computational artifacts," "analyzing these artifacts," and "communicating."

3. James's Website – Deeper Analysis and Critical Thinking

James presented a website for his final project that demonstrated not only his newly acquired skills in html coding, but also impressive data analysis abilities and computer science practices. A screenshot of the main page of his website is visible below:

Figure 8.39: *James's main page of his final project website (with real names of city, school, program, etc. blocked out to protect privacy).*

At the top of James's website are four links to each of the four pages of his website. This page in Figure 8.39 is the homepage ("Home") of James's final project. Depicting an image of his school's main building, James wrote: "What Are [City] High's Students Exposed To?" Below the image of the school, James provided a description of the research project, offering background to his website visitors. When presenting this website to his class on May 14, 2012, James explained while pointing to the paragraph below the image, "So, this is an introduction of what we did with the phones as you already know…" and he read aloud the paragraph that reads:

> Over a course of several weeks, my computer science class was given the opportunity to use phone applications to collect data about the various advertisements and snacks that we are exposed to. After the data collection process came to a close, we were given the chance to analyze our own data to have a better statistical view of what our class was exposed to inside and outside our school lives. This webpage was created in order to show the things that the students of [City] High School are exposed to on a regular basis.

Then, James explained to the class "Now *this* is the actual question…is it safe?" as he pointed to the yellow, centered title near the bottom of the page that said: "The Dilemma: Is it Safe?" James

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clarified that for his research project he wanted to know: "What we're exposed to, is it, like, stimulating to our learning capabilities or is it slowing us down from what we're trying to learn?" During his presentation, James then moved seamlessly into reading the paragraph at the bottom of his homepage that stated:

> The ultimate question remains for the [City High] students that are being exposed to the various advertisements and snacks that are around campus and the school region. As the school board claims responsibility for providing a safe environment for education as a student's right, it must be decided whether the advertisements and snacks are stimulative or slowing our learning capabilities. Through the next pages of the website labeled **Advertisement** and **Snack**, the data that was collected about these subjects will be shown and explained in relation to the safety concerns that revolve around them.

It was interesting that James framed his project in relation to the responsibilities of the school board. He emphasized that the school board "claims responsibility for providing a safe environment for education as a student's right" and, as such, the impact of advertisements and snacking should be examined for their impact on student learning. Unlike most other students in either City or Midtown High, James developed his own research question and clearly stated it within the context of his school community reflecting a "connecting computing" computer science practice. Furthermore, James's ability to create a unique research question reflects an important research skill that few others addressed.

After reading this paragraph during his presentation, James walked across the screen while pointing out how students could visit other pages on his website by clicking on either "Advertisement" or "Snack" at the top of his webpage. He proceeded to demonstrate how this worked by first clicking on the "Advertisement" link which connected to the following webpage:

Figure 8.40: *James's "Advertising" page describing student data results related to advertisements in the community (with real names of city, school, program, etc. blocked out to protect privacy).*

After explaining to his classmates and teacher "so the first link you can see how the advertisements around [Metro City] is, solely on advertisements…" James proceeded to read the top paragraph:

> One of the particular assignments given to the [City] HS students was to take a picture of an advertisement whenever they stumbled upon one while outside. The advertisements can vary from bus ads, posters, to even billboards! After several weeks of collecting data, this is the data analysis of the advertisements around [City] HS.

Then James scrolled down the page to show the first plot while noting, "This is the first bar graph. It's titled 'What advertisements did you see?' And here…oh, I'm not sure if you guys can read this…" because the projection of the website on the front screen was rather small. So James took the time to explain what the graph showed. Walking from the right to the left of the screen, James ran his hand along the lowest bars from the far right of the graph to the highest bars on the left, saying: "you have this pretty basic line. It's all steady." Then James pointed to the y-axis and explained how all these smaller bars were "at the one" meaning only counted once among all the snack entries. At this point, James pointed out that he had to pre-process the data "so that the capital and lower case didn't count." While it wasn't clear exactly what he meant by this (since the graph showed the counts for the same words separately when written with a capital vs. a lower case word—for example, "show" and "Show" were counted as separate bars on the graph although they meant the same thing), it was true that without some level of pre-processing of the data set, this graph would have included many more bars and become even less legible than it was on James's website. James used more advanced data analysis skills to clean up the data set to create a more legible bar plot, revealing more advanced computer science practices in developing computational artifacts. Below is a close-up of this plot:

Figure 8.41: *A close-up of the first bar plot on James's "Advertising" page.*

Moving on in his interpretation of the plot, James noted that the first, two, largest bars on the plot were for movie advertisements. He stated, "So you know, obviously we can infer that we see a lot of movie advertisements, and that's probably due to [the movie industry] being down the block." This recognition of his school's location in relation to the center of America's film industry revealed some thoughtful analysis of the data results. James moved on to read his short paragraph below the bar plot restating his given interpretation:

> From this bar graph that shows the number of advertisements seen, we can conclude that the [City High] students are exposed to movie advertisements the most. The number of advertisements for movies are extrodinarily high, while other reports of different advertisements average at a lower number.

Then, scrolling down to the next bar plot entitled "What Type of Advertisements Did You See?" James pointed to the plot key and explained, "okay, so these are the colors of the graph. On the

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right side here you have the key of the product type. There's beauty, clothing, shoes, accessories. The mustard color is community legal services, ten electronics and applications, entertainment, food and drinks, health and medical, home, transportation, and vice." The image James referred to is shown in detail below:
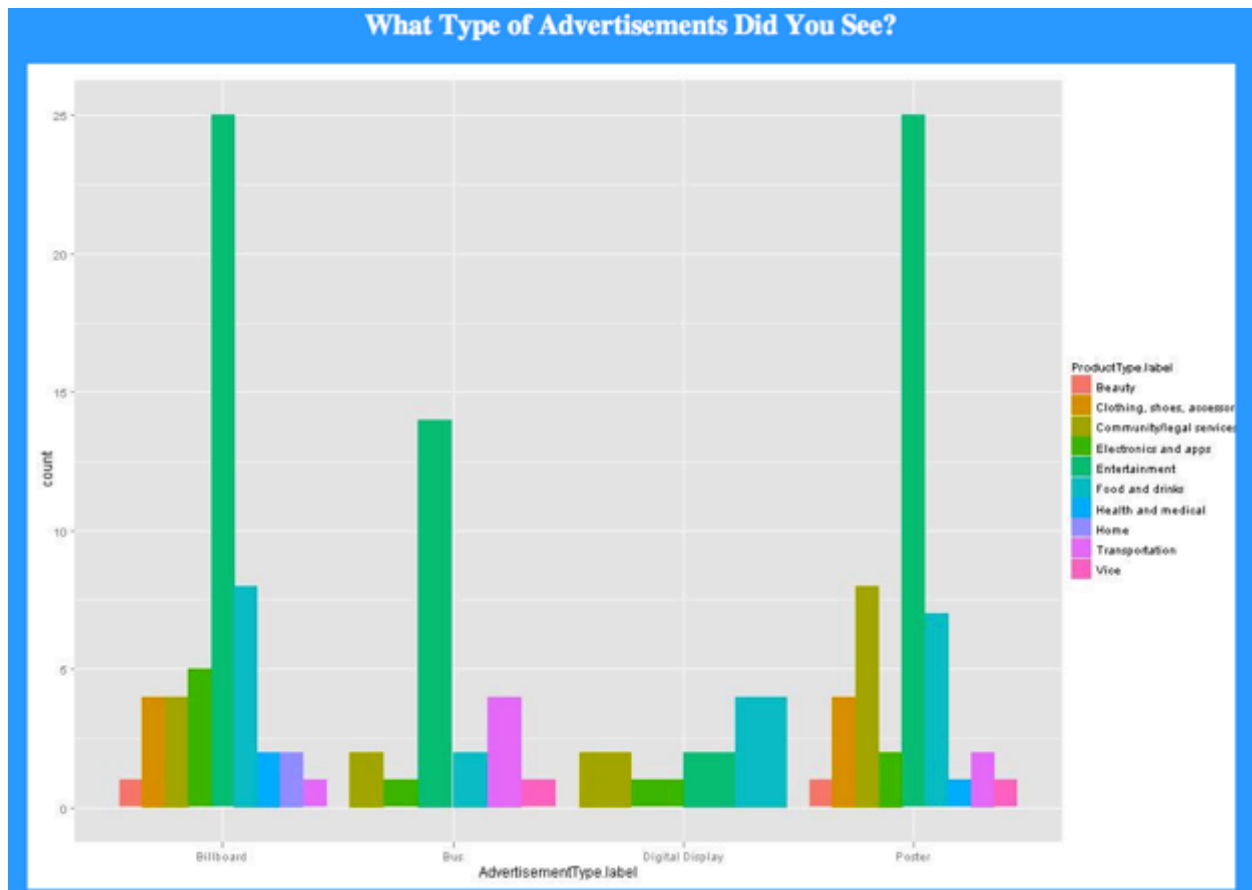
Figure 8.42: *A close-up of James's second graph on his "Advertising" webpage.*

After explaining what each color represented on the bar plot, James pointed to the x-axis labels and noted, "And if you look at the bottom, you can see billboard, bus, digital display, and poster. These are the type of advertisement." Then, moving to the left of this graph projected on the front screen, James explained, "Okay, what's the first thing you can tell is these green bars [pointing to the green bars in the billboard and bus sections of the bar plot] is really really high. If you look at the green color, it's entertainment which is, you know, again, *movies* and

something like that." Here James clarified the connection between this two-variable plot of advertisement item and type in relation to the previous graph. Then he continued, "And the next thing you kind of notice is that billboard and the posters have a lot more count than either the bus or digital display." James gestured at the bars he was talking about in the graph with the billboard and bus bars to the far left having far more data entries in the bar plot than the digital display and poster bars to the far right. James then interpreted this trend, saying, "Maybe this is because, you know, some people don't ride the bus or, for some people, they don't have access to internet at home. I'm not going to give a reason, I'm no sure why. But the green part for both the poster and the billboard are the most popular type of advertisement."

James demonstrated advanced computer science practices in "analyzing the computational artifact" of his graph, not only in the ways he broke down what this colorful bar plot represented and how it related to the previous graph, but also in the ways he offered a tentative suggestion for why people might have seen billboards more often than they saw bus, digital display, or poster advertisements. While he apparently misunderstood what a digital display was—mentioning that one would need to have the internet to see a digital display when in fact, "digital display" refers to digital billboards outdoors—James showed his deeper understanding of what could and could *not* be stated about the data. Recognizing that these graphs did not explain *why* billboards were the most prevalent form of advertisement seen by students, James showed an ability to discern the limits to this data. Furthermore, James could not actually answer the question regarding why billboards were most common from the data set available, showing that his analysis went as deeply as possible for this particular question regarding the types of advertisements seen. The text below this bar plot stated:

> The graph above shows the different **types** of advertisements that the students saw. Just by looking, we can see the extremely high number of entertainment related

advertisements that the students encountered during the data-collecting period. The next inference is that the two most often seen advertisements were either in the form of a billboard of a poster.

After reading this text, James scrolled back up to the top of the webpage and clicked on "Snack" to show his analysis of students' snacking data. This page is shown below:

Figure 8.43: *James's "Snack" webpage (with real names of city, school, program, etc. blocked out to protect privacy).*

James began by reading his top, introduction paragraph on the webpage that explained what

students did to collect snack data for this project. The paragraph read:

> Next in line for the collection of data that the students of [City] HS collected were based on snacks. The snacks could range from a variety of chips, drinks, small meals, or simply fruits. The students were asked to take a picture of the snack before it was consumed and to complete a survey based on the snack they were eating. On the pages below are the analysis of snack data that were collected in the forms of graphs and plots.

Scrolling down to the first graph on his page, James explained, "This is the snack we did with,

that asks who you were with." This graph detail is shown below:

Figure 8.44: *Close-up of James's "Who you snack with" graph on his "Snack" webpage.*

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Interpreting the graph for students and teacher, James ran his hand across the x-axis of the graph while walking from right to left of it and explained, "And as you can see, friends, family, coworkers, classmates, and alone." Then pointing to the y-axis, he noted, "And on the left side is the number of people recorded." Moving on to explain how to read the graph, he said, "Now one thing you can notice, all of the data that are red, right [pointing to the "Alone" bar] mean that the data are up there." He continued, "Mainly alone and family, because you know the time you're with your family might be dinner or something like that." James correctly interpreted the graph showing that the highest number of snacks were eaten when students were alone or with family while also suggesting that this could be because many people tend to eat at least one meal a day with their families. His critical thinking skills and computer science practice of "analyzing the computational artifact/graph" began surfacing when he moved on to explain the blue and smallest bar in the middle of his graph, stating, "And then over here, we have this lonely little bar called 'Coworkers.' Yeah. Okay…" then smiling, James continued pointing to this bar and said, "well none of us work here in this class except for the one teaching it! So I guess this one is Mr. Santos. Thank you for your data!" The class laughed in response.

Of course, James may have been incorrect in his assumption that students don't work. In fact, at least one of his classmates had a part-time job. However, James conducted some on-the-spot interpretation of his data, using a sense of humor to highlight how one of the only people in the classroom who might snack with coworkers would be the one who spends most of the day working, namely, Mr. Santos. James moved on to read his text explaining the graph on the website:

> The graph above explains who the student was with when the snack was being consumed. As you can see, students who reported their snacks were mostly with family members or

friends when they ate the snacks. This shows that the snacks were most likely eaten either at home with family members, or on the school campus with friends.

In this text, James pointed out that students most likely at their snacks ate home or school if they were eating with family and friends. Again, James used tentative language here (e.g., "snacks were *most likely* eaten…") showing his more advanced understanding that generalizations about *where* students snacked could not be made based on this bar graph. However, one could begin to guess at where snacks were eaten based on this information, then confirm that later with other graphs. While James does not provide a graph showing where students ate snacks, he shows creative thinking here when noting that it would be possible for snacks to be eaten mostly at home and school if they are most often eaten with family, classmates, and alone.

During his presentation, James then scrolled down to his next graph entitled "Why Did You Eat The Snack?" recognizing "It's kinda hard reading this, but it's slightly better [than the "What Advertisements" bar plot of the previous page]." This graph is shown below:

Figure 8.45: *Close-up of James's second plot on his "Snack" webpage.*

James pointed to all the smallest bars on the graph and explained, "So here is all the one's. This is whatever had *a* number." In this way, James explained that the smallest bars referred to those reasons for snacking that were least important and only noted once in all the data set. Then, James explained how he had to pre-process this data—going through a more advanced step in data analysis and computer science practices in developing computational artifacts to create a cleaner representation of the data—by noting, "So these are little words that we also have to kind of water down to get a better graph." Similar to the "What Advertised" data, this particular question on the snacking survey asked an open-ended question, "Why did you eat this snack?" As a result, students' responses included full sentences such as "I was hungry" or "It was lunch time." Using his critical thinking skills, James massaged the data to remove any words that would not help illuminate reasons for eating snacks (e.g., "the" or "was" or "I") from the data set before creating this bar graph. His resulting bar plot was, therefore, easier to read and more informative, including mainly words explaining reasons for snacking (e.g., "hungry," "craving," "healthy," etc.).

Moving on to interpret the bar plot, James told his audience while pointing to the largest bar on the plot, "And then the first one you see here, just like the other graph, it spikes all the way up and it even actually goes past the bar graph. So this is 'hungry.' So, you know, it's mainly the reason you ate the snacks, it's because we're hungry. And then all these other various, you know, reasons why was 'healthy,' 'craving'…" then pointing to the several words in a row that included "brownies," "delicious," and "dessert," James also interpreted the graph and noted people may also have had "a sweet tooth." Again, James showed more advanced data analysis skills by moving beyond interpreting which word had the highest count in "Why snack" data to

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also recognize in-the-moment that many of the reasons why people ate snacks shared a sugary feature (such as "sweet," "brownies," "dessert," "fruit," and "goodee").

Moving on to his last computational artifact—a word cloud of what people ate—James noted, "So another perspective to see, this is the *what* they ate now. You can see the biggest word—so the most popular choice—and, as you all can see, is Yoplait yogurt." The graph he was describing is shown below:

Figure 8.46: *James's word cloud as visible on his "Snack" website.*

Moving beyond a surface interpretation of the plot, James went on to explain, "Now the thing [is], you *have* to think about it! This could mean that this Yoplait yogurt is actually eaten by a lot of the students. *Or* [that] there's one guy who likes to eat twenty yogurts a day." The audience laughed at this point as James smiled. While James's delivery was humorous, his deeper analytical skills here were compelling because he was recognizing that the high count of yogurt in this word cloud did not show *who* was actually eating them. Thus, he was explaining that one could not be sure whether or not yogurt was a popular snack among all students, or simply for

one person. This demonstrated advanced computer science practices in analyzing the word cloud

computational artifact. The text for this word cloud on James's website read:

> The word cloud is another way to view the data that was collected about the various snacks consumed by the [City High] students involved with the project. The most obvious observation is that Yoplait yogurt is the most often consumed snack by the students. Following Yoplait is an assortment of pizza, cheez-its, and crackers. The snacks being consumed are all relatively healthy for the students and have low chances to risk the students' health.

After reading this text to his audience, James clarified, "So, of course, you can't die from eating

yogurt or crackers." Then moving on to his last webpage on the website (entitled "Conclusion"),

James returned to answering his original research question about the impact of advertisements

and snacking on City High students. This page is visible below:

Figure 8.47: *James's "Conclusion" Webpage (with real names of city, school, program, etc. blocked out to protect privacy).*

James explained that this conclusion "is taking into account all the data you've seen so

far. Kinda just breaking it all down for you. The first one is advertisement. These two graphs

[pointing to the top graphs] are the ones that were on the 'Advertisement' page and the

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conclusion that I came up with is…" James proceeded to read the text beneath the top two graphs that stated:

> After reviewing all the data and reading the explanations of what the graphs depicted, it can be decided that the advertisements seen and snacks consumed by the [City] HS students are indeed safe to have around. The advertisements that show vice material are generally rare compared to the advertisements that promote entertainment purposes. Although entertainment isn't necessarily stimulant to a student's learning abilities, it does not harm it either. This helps determine that the advertisements around [City] HS are indeed **safe**.

Breaking down his ideas here, James added, "So in other words, you can see that the most popular choice of advertisement we see are movies. And the vice—which is the inappropriate materials—was the lowest average out of all these other sections we have. So although entertainment isn't really helpful or educational, but it doesn't, you know, deprive us of our chances to learn here." James demonstrated strong abilities in bringing together his Advertisement plot interpretations to reach a final conclusion about the impact of advertisements on his school community, skillfully engaging the computer science practice of "communicating his results in context."

Moving on to explain the next panel, James noted that the three bottom plots were the same ones seen on the "Snacks" webpage. He read the text beneath these graphs from his website:

> Other than the advertisements that are being seen around [City] HS, the next issue to resolve is the health concerns involving the snacks consumed by [City] HS students. After displaying the data in a form of plots and graphs, the most popular snack consumed was yogurt. By the [Metro Unified School District] school board, yogurt is not banned from school campuses. This obviously means that yogurt is not an unhealthy snack for the students in [City] HS. Once again, this allows us to determine that the snacks being consumed by the students of [City] HS are also **safe**. There are indeed other snacks being eaten other than yogurt, but the next most popularly consumed snacks are also not considered to be a health harzard on school campuses, allowing the statement that snacks do not demolish the learning environment of [City] HS.

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Again, James showed his ability to culminate all his graph interpretations into his own argument—an important skill for any data analyst in computer science.

Of course, when looking more closely at the advertising and snacking data, one may begin to ask questions about James's interpretation. For example, were there enough data to really come to any conclusion about the risks of advertising or snack food around his school community? Furthermore, when looking closely at the snack word cloud, while the smallest words represent those least eaten, these words *do* include a lot of junk foods such as "snickers" or "candy" or "doritos." This would suggest that snacks may have actually been quite unhealthy overall. It would appear that James did not address the limitations of his research.

Still, the carefulness with which he offered conclusions about why advertisement or snacking data looked as they did in the various plots, or even the ways he questioned interpretations of the prevalence of "Yoplait" in the word cloud revealed stronger critical thinking skills, computer science practices, and data analysis abilities.

Connections to Classroom Context – Mr. Santos Supports Deeper Thinking

Where did Olimpia and James's data analysis skills and computer science practices come from? While these students' critical thinking skills with data and computational artifacts may have been fostered in other contexts beyond Mr. Santos's classroom, Mr. Santos's pedagogical methods of helping students ask questions about their data may have had an important impact on these students' final projects. Throughout the unit, Mr. Santos created a sort of workshop classroom space. Students would be given data sets (from the Centers for Disease Control and Prevention or *Twitter*) that they could play with in JGR/Deducer as a way to learn how to use the data analysis software with other peoples' data. Then, students were given opportunities to examine their own advertising and snacking data using JGR/Deducer. While Mr. Santos might

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begin class with a brief demonstration of how to build a bar plot or map using the data analysis

software, he would leave the majority of class time open for students to answer questions about

the various data sets on their own using the tools he showed them. As they worked, he would

walk around the classroom and assist various students either one-on-one or in small groups.

During these small group facilitations of learning, I observed Mr. Santos ask various

compelling questions that urged students to engage critical thinking skills with their data sets.

For example, consider the vignette below in which Mr. Santos helped Theo make sense of a bar

plot of student data and modeled the process of asking critical questions about what appeared in

the graph:

Theo created a bar plot of "Who you snack with." Mr. Santos asked Theo who people eat
with the most and Theo pointed out "family" on the graph. Then, Mr. Santos asked who people
eat with the least and Theo noted "coworkers." Mr. Santos asked Theo why this might be and
Theo replied, "Because you have the least relationship with them—they're just people you work
with." Mr. Santos nodded his head and asked, "Do you think lots of City High kids work?" Theo
laughed and replied, "No…" while Mr. Santos said, "So that may be another reason why this is
low…Why do you think friends is low?" Theo answered, "people are not friendly." Mr. Santos
laughed with Theo and asked, "Well, why aren't people eating with *friends*?" and Theo said,
"they can be obnoxious!" This comment made Mr. Santos laugh again as he joked, "They can
take your food away!" and Mr. Santos acted out stealing someone else's food while saying, "Hey
man! Can you share that?" Theo laughed and Mr. Santos continued, "So people eat alone…"
(C.FN.5.9.12)

Moving beyond a surface reading of the graph (e.g., "people eat the most often with their family

or alone"), Mr. Santos modeled the process of asking *why* the results might show these trends. In

this way, Mr. Santos encouraged Theo to use his critical thinking skills when engaging the

computer science practice of "analyzing" his bar plot computational artifact.

In other instances, Mr. Santos would ask students questions that pushed them to

reconsider their data interpretations or representations. For example, when Ruby and Maura were

creating maps of bike path data in the city with a practice data set, Mr. Santos asked "How would

you present this data to make it more understandable or accessible? I would experiment! Try

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histogram" (C.FN.4.19.12). Or on another occasion, Andy was struggling to create a subset of bike paths for cyclists using the same data set as Maura and Ruby. When Andy couldn't figure out whether he had done this process correctly or not, Mr. Santos did not give him the direct answer, but helped Andy reach the conclusion himself. First Mr. Santos looked at Andy's data viewer of the subset he had created and asked "What info are you getting here?" Andy didn't understand Mr. Santos's question and so Mr. Santos said, "Look at the type…" Andy widened his eyes and replied, "They're 'bike path.'" Mr. Santos nodded his head, then pointed to the screen saying, "But one is not. It's labeled 'none.' How did you get this in the subset?" Andy noted that he created a subset of shared longitude. Mr. Santos asked him if this kind of longitude-based subset would answer Andy's question about pathways traveled that were not special bike routes. Andy realized his error and fixed his mistake (C.FN.4.19.12).

In simple ways as this, Mr. Santos attempted to support students in experimenting with their data and asking deeper thinking questions about graphical representations. Of course, several students (like Jaime and Eddie) created weaker projects with only surface interpretations of the data suggesting that Mr. Santos could have pushed his students even further in their data analysis and computer science practices. However, Mr. Santos clearly succeeded in creating an environment supporting some deeper thinking with computer science practices as visible in both Olimpia and James's final projects.

Presidential High – Mr. Torres Facilitating Critical Thinking Skills

While Mr. Torres did not assign a final project for his students due to time constraints at the end of the school year, he led a series of open-ended data analysis activities with student snacking data that facilitated learning the same research skills students acquired when creating final projects at the other two schools. There are no final student projects to analyze that reveal

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whether or not students actually learned the data analysis processes that Mr. Torres taught, however the ways in which Mr. Torres supported students' critical thinking when looking at snacking data were important. His pedagogical approach to modeling computer science practices in analyzing computational artifacts and questions about students' data may be central to why his students felt so strongly about their new understandings of data and research as expressed earlier in their interviews.

Consider, for example, the vignette below in which Mr. Torres led students through an analysis of a bar plot showing students' snack location data:

Mr. Torres asked his students, "What else did we plot?" A student called out, "location!" and Mr. Torres replied, "Okay, Hector, where was the location where we frequently snacked the most?" Hector looked at his bar plot and replied, "At the house." Mr. Torres nodded his head and wrote on the board: "At the house/casa." Then he asked, "So in the house, is there your family?" Students said yes and Reina started listing off "cousins, nephews, friends" while Marisa added "grandkids." Mr. Torres asked, "So if lots of people are in the house, is there lots of food to choose from?" Marisa replied smiling, "Oh, yes!" Mr. Torres said, "Okay! So lots of options. So when does family come over?" Manuel noted, "holidays" and other students started calling out all sorts of ideas (e.g., parties, celebrations, family reunions, family talks, football games) and Mr. Torres asked, "Would you say that on special occasions, food is attached? So would you say there is a correlation between food and family?" Students paused and Mr. Torres asked if students knew what 'correlation' meant. Amy asked if it meant "differences or similarities?" To which Mr. Torres replied that she might be correct, but it would be best to find the exact definition. Mr. Torres asked Manuel to look up the definition online, after which Marisa smiled and immediately started competing with Manuel to see who could find the definition the fastest. She started looking up the definition on her mobile phone, trying to beat Manuel at this task. Amy suggested maybe 'correlation' meant "relationship," after which Marisa read loudly from her mobile phone: "It means 'mutual relation of two or more things'." Manuel smiled and laughed at the fact that he couldn't find the definition as quickly as Marisa. Mr. Torres then turned to the class and asked, "Would you say there's a relationship between who you ate with and location?" Students decided this must be true. (P.FN.5.9.12)

During this highly animated interaction, Mr. Torres guided his students through the computer science practice of analyzing the computer-generated bar plot. While one might have ended the data analysis process at deciding which bars were largest and smallest, Mr. Torres led his students through a compelling consideration of various other food consumption features that

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might be related to the snack location graph. By asking his students about who else might be present in the house where people are snacking, what events might bring people together around food at the house, etc., Mr. Torres modeled the sort of critical thinking practices of an advanced data analyst who begins asking *why* the data trended in a specific way. Furthermore, Mr. Torres introduced a new vocabulary term used for talking about data—"correlation"—that none of the students previously knew. Demonstrating her computer literacy skills, Marisa then proceeded to compete with Manuel to find the definition of "correlation" online using her own mobile phone. Students were highly engaged not only with the conversation around the bar plot, but also understanding how to talk about the bar plot relationships—or correlations—in a more meaningful way. Thus, Mr. Torres effectively modeled important computer science practices in "communicating."

After this conversation, Mr. Torres decided to have students also consider potential relationships between snacks and cost. Through this process, Mr. Torres continued pushing students' critical thinking skills about the social contexts of their data collection process with the computer science practice of "connecting computing." This was visible in the vignette below:

Mr. Torres said, "Okay, let's go one more level…snack cost." Displaying the snack cost bar plot that students had already created, he asked, "Isaac, what was the most common cost for snacks?" Isaac replied, "less than $1." Mr. Torres wrote this on the board and asked, "Okay, so can anybody give me some examples?" Students said "hot Cheetos" and then Marisa called out, "What?! Hot Cheetos cost $1.10!! What's wrong with y'all?" and students laughed with her. Belén pointed out that the smaller packs were cheaper and Marisa said that was true, so Mr. Torres wrote on the board "hot Cheetos small" and added the various other snacks under $1 that students called out, including rice crispies, gum, sunflower seeds, m&m's, snicker's, and soda. Then Mr. Torres asked the class, "Do you see these at home?" Students said "not really" and Mr. Torres asked, "With friends do you share them?" and students said "yes" and that "it depends." Mr. Torres asked, "How many of you have these snacks when you're alone but not at home?" About six people raised their hands and Mr. Torres asked, "Is there any different snacks that you eat at home with family? Give me some examples that you would not normally eat on your own…" David noted "red vines" and Belen said "Those cakes…" Mr. Torres asked the class, "What else do you notice? What do these snacks come in?" Students noted that they are purchased in big boxes and Mr. Torres said, "So family sizes—family snacks. Opposed to other

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snacks that come in smaller quantities. Solo snacks…" Then Allison noted, "At home we're sharing but when we're alone, we're not." Mr. Torres asked, "So that has to do with the type of snacks we eat? Anyone agree with that? If you know you don't need to share snacks, does that determine the type of snack you buy?" David replied, "It depends on my mood—if I want a certain kind of candy, then I can buy a small amount, but if I'm on my way home, I know that I need to buy more if my little sister and brother are home because they will ask for some…" Mr. Torres smiled and asked, "Can any of you go home and not be ready to share? Ever been on the other side of the shoe, feeling bad if they don't share their snack with you?" Marisa laughed and joked, "That's my job! To take the snack away from them!" (Marisa is the youngest sibling in her home). Mr. Torres added, "Now think of snack costs. Mom and dad are at the store, and they're going to buy things in larger boxes for the whole family…" Students agreed that when parents are buying for the entire family, they buy things in bulk. (P.FN.5.9.12)

In this discussion of the snack cost plot, Mr. Torres asked questions and modeled the same type of deeper thinking about data that was visible in the previous conversation about snack location. After having students reflect on the types of snacks that they regularly consume that are under $1 (the most common snack cost in the student data), Mr. Torres pushed students to relate this graph to the previous conversation, asking if students were at home when they ate these snacks. Then he asked students to consider whether they commonly eat these cheaper snacks when with friends or alone instead. In this way, Mr. Torres modeled the process of thinking about connections between various aspects of the snacking data, getting students to think more deeply about research context. Students began sharing important reflections on what they do when it comes to buying snacks before heading home and how this might relate to snack cost or location: David explained that he would have to buy multiple of the same snack before going home so that his younger siblings could eat them too, while Marisa noted she would be the younger sibling to steal snacks from her older siblings while at home. Then Mr. Torres related these ideas back to students' reflections that most home snacks are purchased by their parents in bulk sizes. These discussions show how Mr. Torres supported students' critical thinking skills and computer science practices through the data analysis process.

Conclusion

Through an examination of student projects, it becomes visible that none of the students became expert data analysts as a result of this six-week MyData unit. However, the emerging data analysis, critical thinking skills, and computer science practices students demonstrated—through the typical weak to typical strong final projects and in-class discussions—are particularly compelling when considering that this was many students' first experience with data analysis and research. Returning to students' interview testimonies, the majority of students had never really understood what data were before this project, nor had they experienced collecting and analyzing their own data previous to MyData. These learning gains are *significant* for students participating in an introductory computer science course, especially considering current emphases in educational policy and popular media regarding the need to prepare students to understand "Big Data" (see for example Davenport and Patil, 2012; Manyika et al., 2011; Miller, 2013).

Furthermore, students' testimonies revealed important realizations that data analysis and research can powerfully impact their home communities. When asked whether they would enjoy conducting research with mobile phones again, most students definitively stated that they would. When asked what kind of research they would want to conduct in the future, most students described projects that could drive positive social change. Students in *all three* schools described studying topics such as pollution, public transportation, health and exercise practices, racial stereotyping in school, college-going rates, how teachers teach, endangered animals, graffiti on campus, bullying, and various other subjects related to their desires to impact our world. By the end of this unit, students clearly began to see themselves as individuals capable of having a voice

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in their communities, showing an interest and desire to use data analysis in computer science as a tool for civic engagement.

CHAPTER NINE
Community-Driven Learning, Not Tool-Driven Learning:
Final Reflections

"There are no technology shortcuts to good education" (Toyama, 2011a, par. 1)

When Kentaro Toyama founded Microsoft Research India, a computer science lab in Bangalore, he was trying to figure out ways that technology could support economic growth in low-income communities. He worked with various groups, including a rural sugarcane cooperative outside Mumbai and local schools, to develop technology platforms that would improve people's quality of life. After several years, Toyama found himself disillusioned with the mixed results of his efforts. Toyama concluded, "In project after project, the lesson was the same: information technology amplified the intent and capacity of human and institutional stakeholders, but it didn't substitute for their deficiencies" (2011b, par. 6). Technological tools alone were not enough to impact positive social change without the appropriate "intent" and "capacity" already in place.

Nicholas Negroponte's "One Laptop Per Child" (OLPC) organization and various American one-to-one laptop programs are demonstrating similar outcomes. In a randomized evaluation of 319 primary schools participating in the OLPC program in rural Peru, no evidence of impact on school enrollment or Math and Language test scores was visible (Cristia, Ibarrarán, Cueto, Santiago, & Severín, 2012). The authors note:

> [T]o improve learning in Math and Language, there is a need for high-quality instruction…Hence, our suggestion is to combine the provision of laptops with a pedagogical model targeted toward increased achievement by students. Our results suggest that computers by themselves, at least as initially delivered by the OLPC program, do not increase achievement in curricular areas. (p. 20-21)

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Similarly, Maine's statewide one-to-one program (the largest in the U.S.) found little effect on student achievement (Silvernail & Gritter, 2007); a middle school one-to-one program in Texas found reading scores did not improve with computer-use (Shapley et al., 2009); and Michigan's one-to-one program found higher achievement scores in only half of the schools they studied (Lowther, Strahl, Inan, & Bates, 2007). As Goodwin (2011) notes in his review of American one-to-one laptop program evaluations: "Rather than being a cure-all or silver bullet, one-to-one laptop programs may simply amplify what's already occurring—for better or worse—in classrooms, schools, and districts" (par. 16).

These results emphasize that pedagogy matters.

Simply providing the newest technological tools in a classroom will not improve a teacher's ability to explain new ideas or a student's ability to understand the quadratic formula. This was why I chose to focus on the pedagogy of strong computer science teachers as a way to highlight those specific actions that seem to make a difference in student learning with technology. Effective teacher practice driven by an educator's positive "intent" and "capacity" to grow, as highlighted by Toyama (2011b), can tell us a lot about the potential ways computers can impact public schooling.

Yet, let us examine for a moment what "intent" and "capacity" really mean for educators in public schools.

The "Intent" of Public Schooling – Teachers and Educational Institutions

Reflecting on the intentions of the three dissertation teachers, there was a clear dedication to providing the best quality education possible for *all* their students and an obvious love for the art of teaching. These three teachers voiced a desire to ensure that their students gained access to new opportunities, computer science, college, and the experiences that only a privileged minority

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are offered in high school. They were dedicated to addressing equity issues in public education. Furthermore, these educators wanted their students to leave Discovering Computer Science classrooms with a sense of pride, accomplishment, and confidence in the ability to tackle whatever complex problems they might face in the future using their newly acquired critical thinking and analysis skills. This translated to a focus on problem solving processes and creativity—critical computer science practices—rather than just figuring out "the answers" alone. This also resulted in teachers wanting to perfect their teaching expertise. Ms. Mendoza took an online Java class, and all three educators attended professional developments focused on inquiry-based teaching practices in Discovering Computer Science. With teachers' intentions fixed on providing positive computer science learning experiences for diverse students, technology could be used in meaningful ways.

Could one argue, however, that these intentions were not enough? Returning to my findings regarding student learning through the MyData Unit, shouldn't more students have had the types of complex plots and deeper reflections on the limitations of their research that we saw in Soffy or James's projects? While students described gaining new understandings about data and research, couldn't teachers have pushed them even further into the academic aspects of statistical analysis? Mr. Torres and Ms. Mendoza asked important questions about food deserts and the lack of fresh farm produce in their neighborhoods in relation to segregation and urban planning, but couldn't these discussions have been more profound? There was an implied notion that unhealthy food was being dropped into students' communities by some outside force, but there was minimal discussion about nutritional education, health education, or choice. There were few conversations about who was profiting from selling cheap, poor-quality food in students' communities, or discussions about why people choose to eat unhealthy foods. Diabetes

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was discussed as a problem in America, but conversations about how modern relationships with food are affected by advertising, a lack of health education, class struggle, and poverty, were never led in a more complex way. Students and teachers *began* to ask important questions, but how could these questions have been used to transform the ways students actually live?

The fact that most students reported new understandings of data and research in computer science, but not everyone demonstrated the kind of computer science practices and analytic competence we might like to see, is a classic dilemma in introductory instruction of this kind. As an introductory class, one would not expect that students should leave the classroom understanding college-level computer science or statistical analysis. And, indeed, students' learning gains regarding understanding data and acquiring new dispositions toward computer science and research are incredibly important successes within this introductory course context. However, increased motivation to learn computer science is not enough. Students must also gain access to critical content learning and computer science practices as well, especially if we want to ensure equal educational opportunities in computing for all students.

Of course, part of the current challenge in computer science education is coming to a consensus about which key computer science principles and practices should be taught in high school and how to measure student learning of such content and practices. The field of computer science education is beginning to develop new standards and measures of content learning with the creation of the new Advanced Placement Computer Science Principles course and the College Board's 2012 outlining of the computer science practices. While my work begins to describe what these practices in computer science learning look like in the context of classrooms seeking to broaden participation in computing for young women and students of color, an important area of future research would be to further define how to measure this learning.

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And what about the intention of computer-based learning in American schools? Let us consider the tone of current government, public policy, research, and business conversations surrounding 21st century skills. Most discussions about the necessity to prepare children to effectively use computers while acquiring 21st century skills relate to concerns about filling the increasing number of future computing jobs for which most high school graduates today are not properly trained. I am reminded of Althusser's (1971) discussion about education as an Ideological State Apparatus—an institution that serves the needs of the state through ideological influence instead of physical force—whose purpose is to prepare students to enter the workforce. Althusser (1971) wrote:

> [The school] takes children from every class at infant-school age, and then for years, the years in which the child is most 'vulnerable', squeezed between the family State apparatus and the educational State apparatus, it drums into them, whether it uses new or old methods, a certain amount of 'know-how' wrapped in the ruling ideology…Somewhere around the age of sixteen, a huge mass of children are ejected 'into production': these are the workers or small peasants. Another portion of scholastically adapted youth carries on: and, for better or worse, it goes somewhat further, until it falls by the wayside and fills the posts of small and middle technicians, white-collar workers, small and middle executives, petty bourgeois of all kinds. A last portion reaches the summit, either to fall into intellectual semi-employment, or to provide, as well as the 'intellectuals of the collective labourer', the agents of exploitation (capitalists, managers), the agents of repression (soldiers, policemen, politicians, administrators, etc.) and the professional ideologists (priests of all sorts, most of whom are convinced 'laymen'). (p. 155)

Of course, ideologically, we embrace the belief that our schools *should* prepare children for future occupations. How else can our children be expected to survive and thrive in a society based on money in capitalist relations? And many occupations for which people are paid money provide individuals with a sense of fulfillment, giving their lives purpose.

What I would urge us to reflect on, however, is what it really means to prepare students with 21st century skills for the future workforce. Do we teach and learn simply for economic reasons? Do money and profit really need to be the driving forces of public education? And what

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does that look like in most schools? For example, does learning 21st century skills result in students being prepared only to color within the lines, follow orders without question, approach problem solving in a singular way, use technology without considering its impact on the environment and the laborers making technological tools, or use computers merely to further students' personal interests at the expense of the quality of life of others? Which students are being taught to use 21st century skills and computational thinking toward creativity, solving issues related to poverty and disease, healing the environment instead of further depleting our planet's resources, or engaging with their communities to improve our world?

In his book *Why School? Reclaiming Education for All of Us*, Mike Rose (2009) reflects on similar questions when discussing how public education's economic focus combined with standardized testing has resulted in a "pinching of what we talk about when we talk about school…[that] can devolve to procedures, to measures and outputs that constrain what gets taught, how it's taught, and how we define what it means to be an educated person" (p. 26-27). Rose's (2009) description of the current tenor of public discussions regarding education's purpose is worth quoting at length:

> There's not much public discussion of achievement that includes curiosity, reflectiveness, uncertainty, or a willingness to take a chance, to blunder. And how about accounts of reform that present change as alternately difficult, exhilarating, ambiguous, and promising—and that find reform not in a device, technique, or structure, but in the way we think about teaching and learning? Consider how little we hear about intellect, aesthetics, joy, courage, creativity, civility, understanding….Now there *is* an economic discussion of schooling that we ought to hear, but rarely do. This would be a discussion that places individual and school failure in the context of joblessness, health-care and housing security, a diminished tax base, economic policy, and the social safety net. (p. 27)

Indeed, it is important to consider the economic needs of individuals and nation when discussing the purpose of education, but in relation to freedom of thought, intellectual openness, and responsibility to others. If the purpose of learning 21st century skills and computer science—or

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any skill for that matter—is merely to prepare children for future jobs that support America's economic development, then our approach to schooling becomes narrowed. Rose's (2009) words resonate strongly with me when he states:

> I worry that the dominant vocabulary about schooling [economics and standardized testing] limits our shared respect for the extraordinary nature of thinking and learning, and lessens our sense of social obligation. So it becomes possible for us to affirm that the most meaningful evidence of learning is a score on a standardized test, or to reframe the public good in favor of fierce and unequal competition for a particular kind of academic honor. Education is reduced to a cognitive horse race. (p. 29)

I saw clearly what this "cognitive horse race" looked like at the three dissertation schools. Teachers were required to spend valuable class time on the rote memorization of vocabulary unrelated to the day's lesson or course content. Students were constantly being pulled out of class to re-test or prepare for standardized tests, interrupting the flow of more intellectually-engaging projects. Many students were forced to take standardized test preparation courses as their electives instead of fulfilling the classes that would make them eligible to apply to state universities upon graduation. Entire weeks of school were lost as students spent hours filling multiple choice bubbles on state and national exams. And schools struggled to ensure that students were coming to school during these standardized test weeks that many children would rather skip. The greater "intent" of public schooling has been negatively impacted by the constraints of standardized testing pressures driven by a focus on America's economy.

Of course, public schooling's intentions impacted by the constraints of a suffering economy and standardized testing pressures has affected education's capacity to use new technology in innovative and creative ways.

Teacher and Public School "Capacity"

Ms. Mendoza, Mr. Torres, and Mr. Santos reflected important capacities to learn, engage, and experiment with the MyData curriculum in ways that many teachers would have felt too

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intimidated to try. The MyData Unit required that these teachers learn how to use the mobile phone apps, the web front-end tools, and the JGR/Deducer data analysis software program while refreshing their understandings of statistical analysis skills that, for some, had not been employed for nearly a decade. And this teacher "capacity" was visible within the context of teachers being overworked with numerous responsibilities (from sports coaching to after school teaching to organizing senior class activities) *while also* being underpaid and underappreciated (as visible when Mr. Torres lost his teaching position at Presidential High based on seniority). Despite experiencing such stress, these three teachers showed an incredible dedication to their students while maintaining individual capacity to become stellar teachers who wanted to grow.

Unfortunately, few teachers have this kind of capacity. And how can we expect today's educators to have the capacity to be stellar teachers of 21st century skills and computer science if they are treated poorly, overworked, and underpaid? How might public schooling look different if the teaching profession were considered on par with that of a medical doctor, a court judge, or even the President? Why is it that when people declare that they want to be school teachers, they often receive a look of pity, a pat on the shoulder, and a comment such as "What a *noble* thing you have chosen to do…"? Efforts must be made to improve the professional capacity of teachers if we are to expect computer science and 21st century education to positively impact our students' lives. This means respecting educators' work, intellectual ability, and time in ways that our country currently fails to do.

Yet this also means that the capacity of public schools needs to be addressed. Especially when considering the use of innovative curricula employing new technological tools, funding is scarce and the financial cost is huge. Thus technology-based education will only be a waste of money if schools are not provided with the supports necessary to use technology well. If we

intend to prepare children to excel in technology and develop 21st century skills so that they can be creative problem solvers who improve the world, schools will need a different kind of financial and political support that shifts away from the current focus on money for money's sake, or standardized testing as the sole means of measuring student learning.

Of course, many schools then turn to business sponsorships or alliances with corporations, especially when it comes to technology-based learning. Recognizing that business-school alliances can be positive—providing money, materials, and repairs—Rose (2009) cautions us to consider the dangers of these relationships. Beyond the obvious problem that many businesses are driven by tax deductions or by profiting from materials they provide to schools, Rose (2009) highlights how business's influence on the educational sphere has unfortunately resulted in "Kids go[ing] to school to get themselves and the nation ready for the global marketplace, and this rhetoric of job preparation and competition can play into reductive definitions of teaching and learning" (p. 56-57). This is due to a "technocratic-managerial ideology" driving business practice that then pushes schools to be run like a "manufacturing plant" where

> pedagogical wisdom and experiential knowledge of schools are dismissed as a soft or airy distraction. A professor of management tells a class of aspiring principals that the more they know about the particulars of instruction, the less effective they'll be, for that nitty-gritty knowledge will blur their perception of the problem and the application of universal principles of management. (Rose, 2009, p. 57)

This business-driven attitude affecting schools limits their capacity to meet the particular needs of unique communities and pushes education reform conversations away from the particulars of teaching and learning. We cannot let education's capacity be driven by corporate institutions.

Community-Driven Learning, Not Tool-Driven Learning

This brings us back to student learning in the MyData Unit. It was revealing that the learning students valued most related to becoming "researchers" who could positively impact their communities. While such learning about data and research was made possible through students' uses of technology to study snacking and advertising, students' interests in data analysis and research were not driven by the tools themselves. While technology may have initially engaged students' curiosity about the research unit, it was the opportunity to learn more about their communities and have a voice in describing their communities that mattered most. Again we find that intent and capacity mattered more than the technological tool.

When considering the future of technology-based education and computer science in our public schools, this dissertation research has revealed the importance of allowing classroom learning to be driven by student interests, community values, and teacher knowledge in addition to focusing on the computer science content they must learn. Successfully sowing the seeds of student motivation to learn computer science does not come from technology or curricula alone, but also from the important ways teachers and students experience problem solving, computational thinking, and the development of 21st century skills collectively in the classroom.

This work is only one example of the many rich ways that teachers can motivate student interest and engagement with computer science and how students can be empowered by the process of becoming community researchers. The subtleties of teaching and learning in technology-based classrooms are, unfortunately, understudied in the field of education. I believe my findings only begin to show the important ways that many teachers and students are currently striving to make public schooling a more humanizing and enriching place while engaging in rigorous computer science practices. There is still so much more we can learn from the shared

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efforts of diverse individuals in classroom ecologies whose computer science practices are community-driven, not technology-driven.

Appendices

Appendix A – The Advertising MyData Survey App
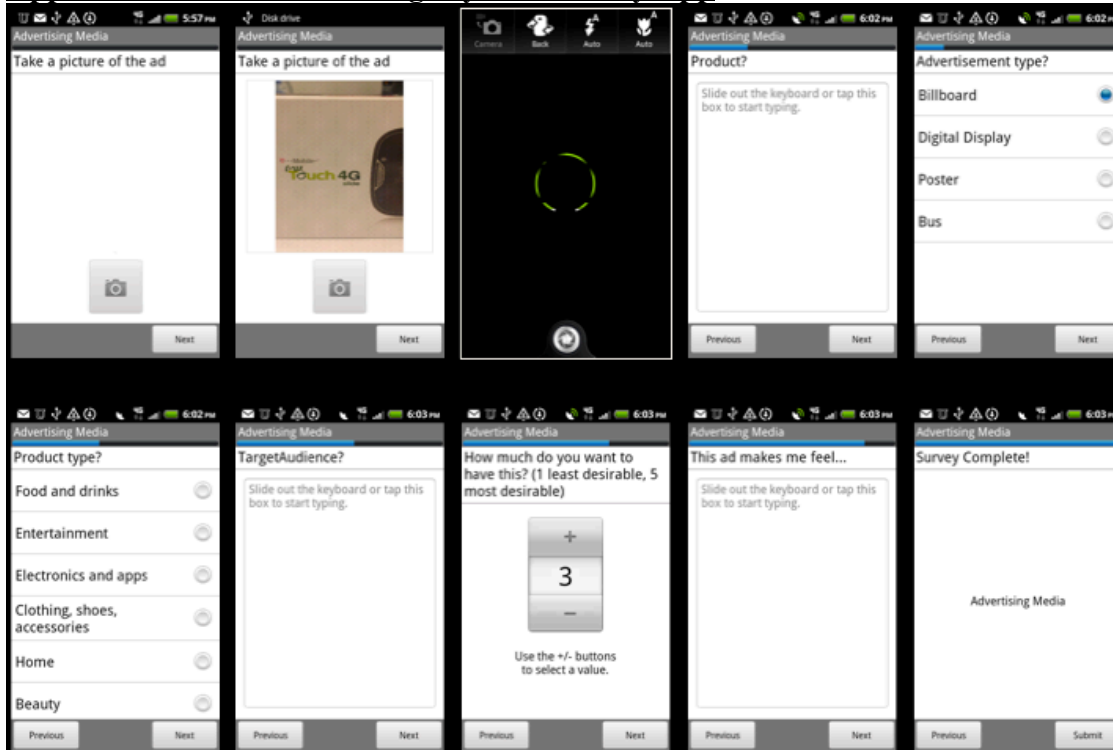
Appendix B – The Snacking MyData Survey App
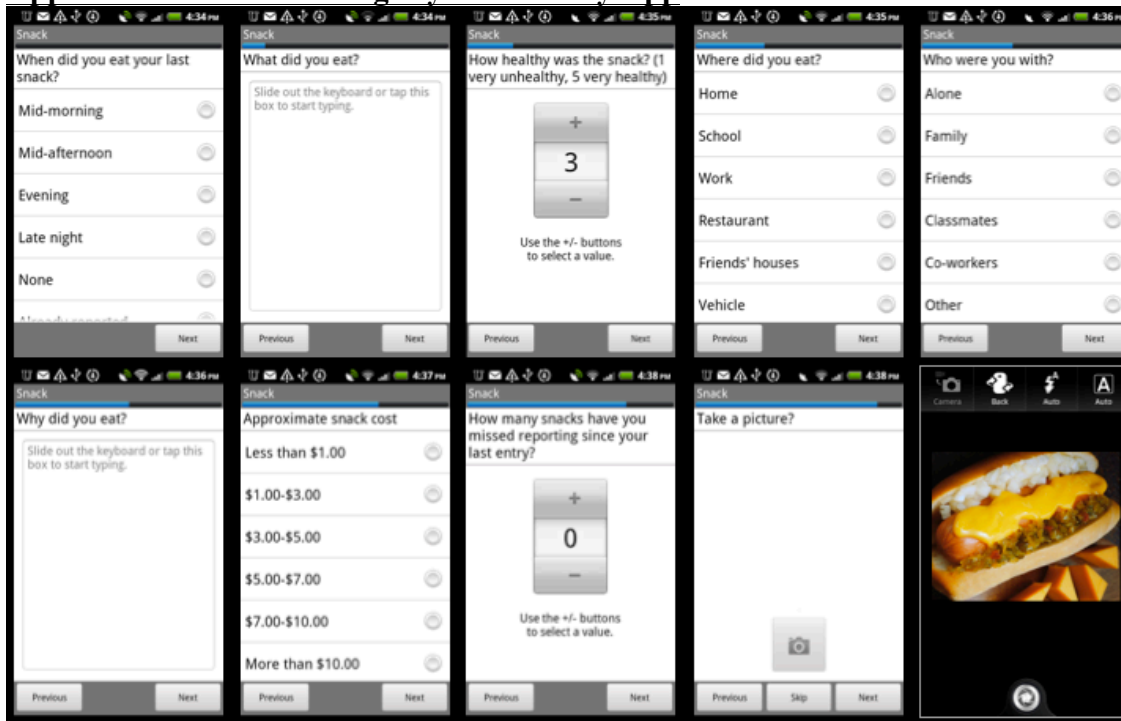
Appendix C – Teacher Interview Questions (December 2011)

Background Information:

1. Can you talk about your teaching background? How did you come to be a teacher?
2. What subjects did you originally want to teach? What are you certified to teach?
3. How did you come about teaching at this school?
4. Why did you begin teaching Discovering Computer Science?
5. How supportive are your administration, counselors, and teacher colleagues for supporting DCS at your school?

Teaching Style:

6. How would you describe your teaching style? (Prompts: student-centered or teacher-directed?
7. Has your teaching style changed over time? How?
8. Do you incorporate inquiry-based learning strategies in your classroom? How? When?
9. What are some things you do to establish your classroom's culture?
10. How do you go about preparing for an DCS lesson?
11. How closely do you follow the DCS curriculum? How do you make decisions about which modifications you make to the daily lesson plans or units?
12. What are some things you enjoy about teaching DCS?
13. What are some things you struggle with as a teacher of DCS?
14. Can you talk about a success story you have had in teaching DCS?

Focus on Students:

15. How would you describe your students?
16. How would you characterize your students' experience with DCS so far this year?
17. What do you want your DCS students to walk away with at the end of the year? (skills/content/habits of mind/goals -- academic, career, etc.) Why those items?
18. How will you know that those goals have been met?
19. What are some things you are doing to make sure your students meet those goals?
20. How do you differentiate for the different needs of your students?
21. What equity issues do you experience in your DCS classroom? How do you see your role in responding to these issues?

DCS Program Experiences:

22. How has the DCS Professional Development workshops you attended impacted your teaching of DCS?
23. What has been the most influential moment for you at any of the PDs you have attended?
24. How has DCS coaching supported your teaching of DCS?
25. What has been the most influential coaching moment for you?
26. How has belonging to an DCS teacher community supported your work as an DCS teacher?
27. What has been the most helpful support (curriculum, PD, coaching, community, institutional support, fieldtrip) that the DCS program has provided you? Why?
28. What additional supports from DCS program or your school/district would further support your teaching of DCS?

Closing:

29. Thinking about the questions you have just responded to what is the main thing you want to continue thinking about/working on?
30. Any questions or comments?

Let's begin by thinking about your teaching style and philosophy…
1. What do you think makes a really good teacher?
2. What do you think makes a really good *computer science* teacher? Is it any different? Why/why not?
   a. If you were to give advice to a novice computer science teacher regarding how best to teach diverse students in Metro City public schools, what would you tell them?
3. In a previous interview, you mentioned that you really like to be student-centered, embracing the diversity of your students and expecting the best of them…
   a. So do you feel like you try to draw from students' real lives when teaching new ideas? How?
   b. Do you think it's important to relate computer science learning to what students learn outside of school or in their personal lives? Why/why not?
   c. I've noticed you incorporate current events and talk about social issues—related to poverty, racism, sexism—in your class. You told me before this is because you like to "address things of the 'isms'" → Why do you do this? Do you think it's important? What do you feel your students gain from these discussions?
4. In that same interview, you also mentioned the importance of having a sense of humor in the classroom—that you always remembered the teachers who made learning fun. Your students have agreed that they enjoy your sense of humor!
   a. Do you feel that laughing helps students learn? How?
   b. How do you think a sense of humor impacts the classroom community? Did you ever notice this before?
5. Do you think it's important to care for your students' well-being? Why/why not?
   a. How do you show that you care? What does caring look like and mean to you?
   b. Do students ever come to you to look for advice or seek your support for issues unrelated to their computer classes with you?
6. How do you promote equity in your classroom?

Now, thinking about your experience teaching MyData…
7. How would you describe your experiences teaching this unit?
   a. What are some things you enjoyed about teaching [MyData]?
   b. What are some things you struggled with as a teacher when teaching [MyData]?
   c. What were some successes that you experienced as a teacher when teaching this unit?
   d. If you could teach the unit again, what would you do differently as a teacher?

Thinking about your students' experiences with MyData…
8. What did you want your students to walk away with at the end of the unit? (Skills? Content? Habits of mind? Goals?)
   a. Why were those items important to you?
   b. What did you do as their teacher to prepare them to meet those goals?
   c. Do you feel that students have met the goals you set as their teacher? How do you know?
9. Thinking about students' final projects:
   a. What were some successes in learning that you saw in their final projects?

b. What were some areas of improvement that you would like to see in future final projects for MyData?
c. If you taught this unit again, would you change anything about the final project process or final product?
10. Can you describe any success stories about your students from the MyData unit?
11. Do you think your students enjoyed using the mobile phones? Deducer/JGR?

Now, thinking about the MyData curriculum, technological tools, and resources…

12. Thinking about the MyData curriculum:
    a. Which of the lessons worked best for you in the curricular unit?
    b. Which of the lessons felt most challenging to teach?
    c. If you could change something in the curriculum, what would you change and why?
13. Thinking about the MyData technology (mobile phones, web front-end, and JGR/Deducer):
    a. What aspects of the technology worked best for you?
    b. What aspects of the technology were most challenging to work with?
    c. I noticed that you didn't use the web front-end with your students. Why not?
    d. If you could change anything with the mobile phones, web front-end, or Deducer, what would you change?
14. Thinking about the MyData resources (coaches, tech support):
    a. What worked for you? What was the most helpful support from either coaches or tech support? Why?
    b. What didn't work for you? What would you change?
    c. What additional supports from the MyData program or your school would further support your teaching the unit?

Finally…

15. Are there any last things you would like to tell me about your experiences with the MyData Unit?

Appendix E – Student Interview Questions

General Questions about Your Teacher:
1. How would you describe this class—Discovering Computer Science—to a friend?
    a. What are some things that your teacher does to make the class as you described (use same terms as student)?
2. How would you describe your teacher to a friend?
3. What do you like best about your teacher? Explain.
4. What makes a teacher a "good" teacher? Describe some characters of a "good" teacher.
    a. Do you think your teacher has any of these qualities? Which ones?
5. What makes a person a "bad" teacher?
    a. Do you think your teacher has any of these qualities? Which ones?
6. What are some things your teacher does that helps you learn in this class?
7. What are some things your teacher does that DOESN'T help you learn?

Do Teachers Connect Learning to "Real Life"?
8. Do you feel like your teacher makes connections between what you're learning in class and what you do outside of class? If yes, How?

9. I noticed that your teacher likes to give real life examples a lot. Does this help you? Why or why not?

Connecting Learning to Social Issues

10. Does your teacher ever talk about social issues related to race, gender, social class, or more? If so, can you describe an example?
    a. Did you expect to talk about these things in a computer science class? Was it a surprise?
    b. Do your other teachers also talk about these things in their classrooms?
    c. Do you think these issues are important to talk about in a computer class? Why or why not?
        i. Optional question: How have these topics impacted your understanding of CS in the world?

Teachers and a Sense of Humor

11. Does your teacher make you laugh? How?
    a. Has laughing while you learn ever helped you learn better? In what ways? Or in what ways has it not been helpful?
12. In what ways does laughing and joking in the classroom help? In what ways does it not help?
    a. Do you think it's important for teachers to have a sense of humor? Why/why not?

Relationships/Authentic caring

13. Do you feel like your teacher makes an effort to know how you're doing personally as well as in the class?
14. Do you think your teacher cares about you and your well being? If yes, how do you know? Provide some examples
    a. IF YES: How has your teacher's caring affected your attitude about learning in this class?
        i. Does it make you want to work harder?
        ii. Does it make you want to come to class more?
        iii. Does it make you pay attention because you don't want to let the teacher down?
    b. Do you think it's important for teachers to care about their students? Or do you think it doesn't matter?

Student Learning

15. How would you define "learning"?
    a. How do you know when you've "learned" something, either in school or in life?
16. What have you "learned" by doing this project with the mobile phones?
    a. What do you wish you learned more of?
    b. What did you struggle with?
17. How will you use what you did in this mobile phone unit in other aspects of your life?
18. If your friend asked you about what you're doing with the mobile phones in this unit, how would you describe your project and what you're learning?
19. If you did this same research project about snacking/eating and/or advertising in the community WITHOUT mobile phones…
    a. …how would it be different?
    b. …how would it be similar?

20. Did you enjoy getting to use the mobile phones in this computer project? Why or why not?
     a. How was this project different from other projects in this class? Did it help you learn more than in other units?
21. After doing this mobile phone project, how would you describe what "data" are and what are their uses?
     a. Have you learned anything new about data or research?
22. After this experience, are you more or less interested in learning about data?

Appendix F – Discovering Computer Science Beginning of Course Student Survey

SECTION 2: Experiences with Computer Science

*1. What school do you go to?

*2. What grade are you in?
- ◯ 9th grade
- ◯ 10th grade
- ◯ 11th grade
- ◯ 12th grade

*3. What is your teacher's name?

how the Annotations Toolbar **in this class?**
- ◯ The class fits my schedule
- ◯ I need a computer class
- ◯ A friend told me about the class
- ◯ I like the teacher
- ◯ I am interested in computers
- ◯ A counselor recommended the class
- ◯ I was put in this class
- ◯ Other reason (please specify)

*5. What do you want to learn about computing/computers in this class?

*6. I learn best when:

○ Working in a group of three or more people.

○ Working alone.

○ Getting help from a friend.

○ Getting one-on-one help from the teacher.

○ Other (please explain in the box below)

Other (please specify)

*7. This class is called Discovering Computer Science. What does Discovering Computer
Science mean to you?

*8. What do you think it might mean to "think like a computer scientist?"

*9. On a scale from 0 to 10, how would you rate your knowledge level in each of the following areas?

	None (I don't know this topic) 0	1	2	3	4	Intermediate 5	6	7	8	9	Expert (I could teach my friends about this) 10
How computers accomplish their tasks	○	○	○	○	○	○	○	○	○	○	○
Problem solving techniques	○	○	○	○	○	○	○	○	○	○	○
Creating and evaluating user-friendly web sites	○	○	○	○	○	○	○	○	○	○	○
Programming a computer	○	○	○	○	○	○	○	○	○	○	○
Robotics / Programming and building robots	○	○	○	○	○	○	○	○	○	○	○
Computer modeling of real life situations and analysis of data	○	○	○	○	○	○	○	○	○	○	○

*10. How would you rate your interest level in learning about computer science?

○ Not interested   ○ A little interested   ○ Somewhat interested   ○ Very interested

Please give your opinion on each of the following statements.

Remember that there are no wrong or right answers. All of your answers will be confidential.

*11. The challenge of computer science does NOT appeal to me.

○ Strongly Agree

○ Agree

○ Disagree

○ Strongly Disagree

○ Not Sure

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*12. I will need computer science skills for my future work/career.

- ○ Strongly Agree
- ○ Agree
- ○ Disagree
- ○ Strongly Disagree
- ○ Not Sure

*13. I would like to continue taking computer science classes after I graduate.

- ○ Strongly Agree
- ○ Agree
- ○ Disagree
- ○ Strongly Disagree
- ○ Not Sure

*14. I would be interested in taking another computer science class after I complete this one.

- ○ Strongly Agree
- ○ Agree
- ○ Disagree
- ○ Strongly Disagree
- ○ Not Sure

*15. I would like to major in computer science in college.

- ○ Strongly Agree
- ○ Agree
- ○ Disagree
- ○ Strongly Disagree
- ○ Not Sure

*16. I take computer science classes because I know how useful they are.

- ○ Strongly Agree
- ○ Agree
- ○ Disagree
- ○ Strongly Disagree
- ○ Not Sure

*17. Knowing computer science will help me earn a living.

- ○ Strongly Agree
- ○ Agree
- ○ Disagree
- ○ Strongly Disagree
- ○ Not Sure

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∗18. I expect to have little use for computer science when I finish high school.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

∗19. Taking computer science classes is a waste of time.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

∗20. I will use computer science in many ways throughout my life.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

∗21. In terms of my adult life, it is NOT important for me to do well in computer science in high school.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

∗22. Computer science is a worthwhile and necessary subject.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

∗23. Once I start working on a computer science problem or assignment, I find it hard to stop.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

∗24. Computer science is enjoyable and stimulating to me.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

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*25. When a computer science problem comes up that I can't solve immediately, I stick with it until I have the solution.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

*26. Computer science is boring.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

*27. When a question is left unanswered in computer science class, I continue to think about it afterward.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

*28. I would rather have someone give me the answer to a difficult computer science problem than have to work it out for myself.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

*29. Outside of computer science class, please check the boxes next to activities that you do on a computer or laptop.

☐ Homework   ☐ Music downloads   ☐ Computer programming
☐ Search the Internet ☐ E-mail   ☐ I don't have access to a computer or laptop outside of school
☐ Video Games   ☐ Instant Messaging   ☐ Other (please explain in the box below)
☐ My Space/Facebook ☐ Web page design

Other (please type in the box)
[   ]

Please answer the following questions. All of your answers will be confidential.

SECTION 3: Future Plans

*30. Can you see yourself working in a job that is related to one of the following fields in your future?

	Definitely Not	Maybe	Probably	Definitely Yes	I Don't Know
Math	◯	◯	◯	◯	◯
Science	◯	◯	◯	◯	◯
Computer Science	◯	◯	◯	◯	◯
Technology	◯	◯	◯	◯	◯

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*31. For the field that you chose in question #30, explain what type of work you would like to do in the future.

[text box]

*32. Are you planning on graduating high school on time?

○ Definitely
○ Maybe
○ No
○ I don't plan on graduating from high school
○ I don't know

*33. After high school, which of the following options will you most likely pursue?

○ Get a job
○ Go to trade school
○ Go to community college
○ Go to a 4-year university
○ Other (please explain in the box below)

Other (please specify)
[text box]

*34. Based on your answer to the previous question above (#31), what job would you pursue or major/topic would you choose to study in college/trade school?

[text box]

35. Who in your family has attended college? (Check all that apply.)

☐ Mother
☐ Father
☐ Sibling (Brother and/or Sister)
☐ Grandmother
☐ Grandfather
☐ No one

Other (please specify)
[text box]

36. How would you describe your ethnicity? (Mark ALL that apply.)

☐ African American / Black
☐ Asian American / Pacific Islander
☐ Latino / Hispanic
☐ White / Caucasian

Other (please specify)
[text box]

37. What is your gender?

○ Female
○ Male

Appendix G – Discovering Computer Science End of Course Student Survey

SECTION 2: Experiences with Computer Science

*1. What school do you go to?

[_____]

*2. What grade are you in?

◯ 9th grade

◯ 10th grade

◯ 11th grade

◯ 12th grade

*3. What is your teacher's name?

[_____]

*4. Rate how much you liked learning each of the following:

	I disliked learning this.	I neither disliked nor liked learning this.	I liked learning this.	I loved learning this.	I did not learn about this.
The different fields in which computers are used.	◯	◯	◯	◯	◯
Problem solving techniques.	◯	◯	◯	◯	◯
Web site design.	◯	◯	◯	◯	◯
Programming/Scratch.	◯	◯	◯	◯	◯
Robotics/Programming robots.	◯	◯	◯	◯	◯
Data Analysis	◯	◯	◯	◯	◯

*5. In addition to the items listed in the previous question what else did you learn in this course?

[_____]

*6. In this course, I learned best when:

◯ Working in a group of three or more people.

◯ Working alone.

◯ Getting help from a friend.

◯ Getting one-on-one help from the teacher.

◯ Other (please explain in box below)

Other (please specify)

[_____]

*7. Thinking about the different projects you have done, what might it mean to think like a computer scientist?

[_____]

*8. Think about one project you created in Exploring Computer Science.

Briefly describe a challenge/problem you faced in creating this project, and how you solved the problem.

[_____]

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*9. How has your understanding of computer science changed as a result of Exploring Computer Science?

[text box]

*10. Complete the following statement: Because of Exploring Computer Science I am....

[text box]

*11. On a scale from 0 to 10, how would you rate your knowledge level in each of the following areas?

	None (I don't know this topic) 0	1	2	3	4	Intermediate 5	6	7	8	9	Expert (I could teach my friends about this) 10
The different fields in which computers are used	○	○	○	○	○	○	○	○	○	○	○
Problem solving techniques	○	○	○	○	○	○	○	○	○	○	○
Creating and evaluating user-friendly web sites	○	○	○	○	○	○	○	○	○	○	○
Programming a computer / Scratch	○	○	○	○	○	○	○	○	○	○	○
Robotics / Programming and building robots	○	○	○	○	○	○	○	○	○	○	○
Data analysis	○	○	○	○	○	○	○	○	○	○	○

*12. How would you rate your interest level in learning about computer science?

	Not interested	A little interested	Somewhat interested	Very interested
When I began this class	○	○	○	○
After taking this class	○	○	○	○

Please give your opinion on each of the following statements.

Remember that there are no wrong or right answers. All of your answers will be confidential.

*13. The challenge of computer science does NOT appeal to me.

○ Strongly Agree

○ Agree

○ Disagree

○ Strongly Disagree

○ Not Sure

*14. I will need computer science skills for my future work/career.

○ Strongly Agree

○ Agree

○ Disagree

○ Strongly Disagree

○ Not Sure

*15. I would like to continue taking computer science classes after I graduate.

○ Strongly Agree

○ Agree

○ Disagree

○ Strongly Disagree

○ Not Sure

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*16. I would be interested in taking another computer science class after I complete this one.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

*17. I would like to major in computer science in college.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

*18. I take computer science classes because I know how useful they are.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

*19. Knowing computer science will help me earn a living.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

*20. I expect to have little use for computer science when I finish high school.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

*21. Taking computer science classes is a waste of time.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

*22. I will use computer science in many ways throughout my life.

◯ Strongly Agree
◯ Agree
◯ Disagree
◯ Strongly Disagree
◯ Not Sure

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*23. In terms of my adult life, it is NOT important for me to do well in computer science in high school.

◯ Strongly Agree

◯ Agree

◯ Disagree

◯ Strongly Disagree

◯ Not Sure

*24. Computer science is a worthwhile and necessary subject.

◯ Strongly Agree

◯ Agree

◯ Disagree

◯ Strongly Disagree

◯ Not Sure

*25. Once I start working on a computer science problem or assignment, I find it hard to stop.

◯ Strongly Agree

◯ Agree

◯ Disagree

◯ Strongly Disagree

◯ Not Sure

*26. Computer science is enjoyable and stimulating to me.

◯ Strongly Agree

◯ Agree

◯ Disagree

◯ Strongly Disagree

◯ Not Sure

*27. When a computer science problem comes up that I can't solve immediately, I stick with it until I have the solution.

◯ Strongly Agree

◯ Agree

◯ Disagree

◯ Strongly Disagree

◯ Not Sure

*28. Computer science is boring.

◯ Strongly Agree

◯ Agree

◯ Disagree

◯ Strongly Disagree

◯ Not Sure

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★29. When a question is left unanswered in computer science class, I continue to think about it afterward.

◯ Strongly Agree

◯ Agree

◯ Disagree

◯ Strongly Disagree

◯ Not Sure

★30. I would rather have someone give me the answer to a difficult computer science problem than have to work it out for myself.

◯ Strongly Agree

◯ Agree

◯ Disagree

◯ Strongly Disagree

◯ Not Sure

★31. In what ways have you applied the knowledge and skills you have learned in Exploring Computer Science to activities outside of your ECS class?

☐ Designed a webpage

☐ Created a computer program

☐ Started a blog

☐ Joined a robotics team

☐ Taught someone how to use Scratch

☐ Learned or explored other programming languages

☐ Developed a mobile phone app

☐ Created a video game

☐ I don't have access to a computer or laptop outside of school

☐ Other (Please explain in the box below)

Other (please type in the box)

[   ]

Please answer the following questions. All of your answers will be confidential.

SECTION 3: Future Plans

★32. What are some ways that this Exploring Computer Science course has influenced your plans for the future?

[   ]

★33. After high school, can you see yourself working in any of the following fields or in occupations related to any of the following fields?

	Yes	No	Don't Know
Math	◯	◯	◯
Science	◯	◯	◯
Computer Science	◯	◯	◯
Technology	◯	◯	◯

★34. Are you planning on graduating high school on time?

◯ Definitely

◯ Maybe

◯ No

◯ I don't plan on graduating from high school

◯ I don't know

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*35. After high school, which of the following options will you most likely pursue?

◯ Get a job

◯ Go to a 4-year university

◯ Go to community college

◯ Go to trade school

◯ Other (Please explain in the box below)

Other (please specify)

[ ]

*36. Based on your answer to the previous question above, what job would you pursue or major/topic would you choose to study in college/trade school?

[ ]

37. Who in your family has attended college? (Check all that apply.)

☐ Mother

☐ Father

☐ Sibling (Brother and/or Sister)

☐ Grandmother

☐ Grandfather

☐ No one

☐ Other (Please explain in the box below)

Other (please specify)

[ ]

38. How would you describe your ethnicity? (Mark ALL that apply.)

☐ African American / Black

☐ Asian American / Pacific Islander

☐ Latino / Hispanic

☐ White / Caucasian

☐ Other (Please explain in the box below)

Other (please specify)

[ ]

39. What is your gender?

◯ Female

◯ Male

40. What else would you like to add about your experience with this course?

[ ]

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Appendix H – Student Project Coding Rubric

Student Name:	Absent (Does not meet objective)	Poor (Objective is met, but shows little depth or understanding of the data)	Average (Objective is met and demonstrates a straightforward analysis with no deeper/new conclusions)	Excellent (Objective is met with careful attention paid to both presentation and content, reflecting student thinking going deeper with new conclusions and questions)
1. Does the project explain the student's main research questions?				
2. Does the project describe the student's main conclusions/hypotheses?				
3. Does the project illustrate/explain the student's conclusions/ hypotheses with evidence from the data collected?				
4. Does the project use other images or information from the internet to illustrate/ explain the student's argument or ideas?				
5. Does the project describe limitations to this study?				
6. Does the project raise new questions as a result of the project findings?				
7. Does the project demonstrate attention to presentation looks/style?				

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