CASE STUDY ANALYSIS OF MATHEMATICS LITERACY WORKERS' IDENTITY AND UNDERSTANDING OF NUMBERS WITHIN A COMMUNITY OF PRACTICE

by

DENISE NATASHA BREWLEY-CORBIN

(Under the Direction of Dorothy Y. White)

ABSTRACT

The purpose of this study was to examine how the experiences of African American college mathematics literacy workers (CMLWs) and high school mathematics literacy workers (MLWs), within a community of practice namely the Young People's Project (YPP) Chicago, influence their identities. This study also examined the mathematics strategies and understanding of number concepts participants had as a result of their involvement in a Flagway Game workshop training. The YPP is a youth empowerment and after-school mathematics initiative created by students in Jackson, Mississippi. The Flagway Game was a number theory game derived from the Möbius Function, to help students expand their understanding of natural numbers. The focus of this study was an MLW Flagway Game workshop training, which took place over 4 weeks at Abelin High in January 2007.

The study used interpretive qualitative case study methodology (Yin, 2003), grounded within a theoretical framework of Wenger's (1998) communities of practice (CoPs). Interviews were conducted with participants where they were asked to complete mathematical tasks to determine their levels of understanding of some number concepts used in Flagway. Participants were also asked to reflect on their experience in Flagway training and how that experience shaped their mathematics literacy work. Within-case analyses as well as cross-case analysis of participant findings were conducted. Participant responses were also analyzed using Wenger's three modes of belonging: engagement, imagination, and alignment, as well as from a critical race theory (CRT) perspective using counter-narratives, which showed how they worked towards mathematics literacy for liberation contrary to dominant narratives of failure and passivity.

There were common themes of identity across participants, which influenced how they understood number concepts. CMLWs and MLWs viewed themselves as being; role models, agents of change, and doers of mathematics. There were also common themes of mathematics strategies and understanding of numbers across participants. CMLWs and MLWs used different memorization strategies and also identified ways in which their flexibility with numbers were enhanced as result of their work with the Flagway Game. The CMLWs were more likely than the MLWs to link their practice to a broader community of mathematics literacy workers. The CMLWs structured their practice to align with future pursuits. CMLWs and MLWs used persistence and a commitment to their community in obtaining mathematics literacy for themselves and for others.

INDEX WORDS: Mathematics Education; The Young People's Project; The Algebra Project; Mathematics Literacy; Mathematics Literacy Workers; Student Involvement in School Reform; Student Learning; Identity; Communities of Practice; Critical Race Theory

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DEDICATION

For my mother, thanks for giving me the opportunity to get a good education.

For my sisters Dee Dee, Katrine, and Nicole, Sis says it's possible.

For my brothers Fabian and MoMo, thanks for always being there for me no matter what.

For my nieces Nadiyah, Sanaa, Indigo and Alexis, the future is yours.

For my nephews, Bryce, Ezekiel and Michael, don't be afraid to realize your dreams.

For my booba dooba, Solomon Yao, Mommy loves you!

To all the young people. RISE UP!

Change begins and ends with you.

May your actions today serve as inspiration for transformation tomorrow.

Yes, you can.

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CHAPTER 1

INTRODUCTION

How the Study Began

> How can young people take ownership of math literacy and be successful in today's society? Young People's Project makes the argument that mathematics is important and the Algebra Project provides the space for young people to take that ownership. Algebra Project also believes that part of the goal is not to articulate a full vision for mathematics reform. Young people must be a part of the decision making in articulating that vision. (Karima, Math Literacy Worker)

A mathematics literacy worker at an Algebra Project community-organizing meeting in Atlanta, spoke these words in 2004. Reflecting back on that day and my notes from the meeting, two things came to mind. First, there were a number of community members joined together, discussing the mathematics education of Black children. The room was filled with community organizers, activists, school administrators, university educators, parents, and teachers. The second thing that came to mind was that there were young people there as well. The young people at this meeting were confident in their ability to perform in mathematics and saw themselves as capable of changing the way mathematics could be taught to their peers. They were also making the case for the importance of algebra and describing an organization they created to help students learn mathematics. The young people I am referring to formed the youth arm of the Algebra Project's mathematics initiative, the Young People's Project (YPP), and their work as mathematics literacy workers represented a different aspect of community outreach and reform efforts in mathematics teaching, learning, and curriculum development. Their work represented a *youth-led* initiative to transform mathematics education.

Throughout my schooling, I was an average student in mathematics. When I went to college, even though I was somewhat apprehensive, I decided to pursue mathematics as a discipline of study. I was told repeatedly that only mathematically talented students should pursue the discipline as a major. I decided to study mathematics anyway because I wanted to disprove that assumption. Even though I worked diligently, the mathematics was tough to grasp at times. One of the most important decisions I made while in college, which transformed my understanding and the way I thought about mathematics, was the decision to work as a peer tutor in the college's mathematics tutoring laboratory. As a peer tutor, my mathematics literacy grew over time, and my ability to conceptualize mathematics in broader ways also grew. I also had the opportunity to help students who had various difficulties. The students I worked with had a wide variety of backgrounds. They had taken courses like Algebra II, Pre-Calculus, and Advanced Placement Calculus in high school but had graduated with serious deficiencies in these subjects.

Through the practice of tutoring my peers to improve *their* understanding in mathematics, *my* confidence and understanding in mathematics shifted over time. Engaging in mathematics in a social context influenced my learning and my ability to communicate mathematical ideas to others, and that experience ultimately helped to shape my mathematics literacy and mathematics identity. Mathematics identity, as defined by Martin (2007):

> Refers to the dispositions and deeply held beliefs that individuals develop about their ability to participate and perform effectively in mathematical contexts and to use mathematics to change the conditions of their lives. A mathematics identity encompasses a person's self-understandings and how they are seen by others in the context of doing mathematics.…A mathematics identity is expressed in narrative form as a *negotiated* self, is always under construction, and results from the negotiation of our own assertions and the external ascriptions of others. (p. 150)

I believe that learning is connected to identity and identity is connected to learning. Today, I continue to help others understand and engage in mathematics. My engagement in mathematics continues to influence how I see myself, deepens my mathematical content knowledge, and also creates possibilities for thinking about mathematics in new and different ways.

Reflecting on my personal growth in mathematics through interaction with others, I wanted to study young people whose primary goal was to help their peers learn mathematics. I considered questions like the following:

- How has the experience of helping others learn mathematics influenced the mathematics literacy of those doing the teaching?
- How has working with young people shaped how young people do mathematics and affected their engagement in mathematics?
- What identities do young people have who work in these contexts?

Considering the work of the YPP as a social context for engagement in mathematics, I wanted to gain a deeper understanding of the role that young people have in the mathematics teaching of their peers. As young people take on the role of teacher, facilitator, and mathematics literacy worker in their practice, I also wanted to know how they see themselves as *doers of mathematics* (Martin, 2000, 2007) and what other aspects of their identity are shaped in the context of the mathematics literacy work they participate in. YPP became the focal point for this dissertation study because its members engage in this kind of transformative work. YPP's work in many ways underscores the importance of students' critical involvement in mathematics education, from their impetus to do mathematics literacy work to their understanding of its impact in their local community. This was my initial impetus for this study.

Statement of the Problem

The Mathematics Literacy Issue

As our society grows in complexity, attributed to technological advancement, in order for all citizens, regardless of race, to compete fully in society, they must have an adequate level of mathematics literacy. Unfortunately, the gap has widened between the mathematical needs of citizens and the mathematical capabilities of individuals (Quality Literacy Design Team, 2001). Many Black students, in particular, cannot take full advantage of careers in the sciences and technologies due to insufficient knowledge in mathematics. Mathematics literacy enables individuals to improve their life chances in study and work. It also enables individuals to participate more fully in society by making more informed economic and political decisions. Acquiring mathematics literacy also provides individuals with the opportunity to empower themselves and to broaden their perspective and awareness of issues around them (Ernest, 2002). Some argue that the citizenship issue is embedded in the mathematics literacy issue (Kamii, 1990; Martin, 2007; R. P. Moses, 1994; Silva, Moses, Rivers, & Johnson, 1990). Citizenship refers to the rights and responsibilities of individuals participating in society for the betterment of themselves and their community. Today, mathematics literacy has become a question of citizenship for many poor and minority students in the same way that having literacy and a modest interpretation of the Constitution was a requirement for citizenship for poor Mississippi sharecroppers accessing the right to vote in the 1960s (R. P. Moses, 1994; R. P. Moses & Cobb, 2001). But even then, there was a necessity for those who were denied access to the political system to make the case for themselves that they too could articulate their position by demanding their right to vote. Today, a similar articulation is necessary for Black students in mathematics. These students must make the case for themselves that acquiring mathematics literacy is not only a citizenship issue, but also a *civil rights issue* (R. P. Moses, 1994; R. P. Moses & Cobb, 2001). Further, it should be the right of every citizen to be able to access quality mathematics education to become mathematically literate. When we prepare students for citizenship, we are preparing them to take a position on issues and utilize their voices effectively in dealing with these issues and beyond (Rudduck, 2007).

The issue of Black student achievement has received an unprecedented focus in educational research (Comeaux & Jayakumar, 2006; King, 2005; Ladson-Billings, 1994, 1995, 2000b; Ogbu, 2003) in general and mathematics education (Anderson, 1990; Hughes, 2003; Johnson, 1984; Lubenski, 2002; Martin, 2000; Rech & Harrington, 2000; Secada, 1992; Stiff & Harvey, 1988; Tate, 1997a) in particular. One aspect of the problem has been the challenge for many Black students to demonstrate a competency in mathematics, not only in schools, but also on standardized tests. Many Black students have struggled to develop mathematics literacy skills that will enable them to perform well on national assessments. Data from a recent National Assessment of Educational Progress (NAEP) report on mathematics assessment showed that the average 12^{th} grade score for Black students was 127, as compared to the national average of 150 (National Center for Education Statistics, 2005a). The NAEP assessment tested students' mathematics proficiency on topics ranging from number properties and operations, measurement, geometry, and algebra. Despite moderate gains on NAEP assessments over the past 30 years, Black students still fare poorly in comparison to other racial and ethnic groups (NCES, 2000). Furthermore, evidence suggests that this gap in mathematics achievement may be widening (Campbell, Hombo, & Mazzeo, 2000; Jencks & Phillips, 1998; Lee, 2002; Martin, 2003).

Mathematics literacy and proficiency has become a fundamental requirement for students taking advanced mathematics courses, not only in high school, but also at post-secondary institutions. Because of a lack of preparation in mathematics at the secondary level, students are unable to take higher-level mathematics courses at post-secondary institutions. One contributing factor is the number of students entering post-secondary institutions requiring remedial mathematics. In a recent article, Dillon (2009) cited other contributing factors for students taking remedial classes such as poorly ran schools and a lack of connection between high school and colleges. In an NCES (2003) study, 97% of all public 2-year institutions offered remedial mathematics courses. This statistic compared to other types of post-secondary institutions, which offered remedial mathematics courses such as, 78% of public 4-year institutions and 49% of private 4-year institutions. While these statistics have improved in recent years, there are still a large proportion of students who continue to take remedial courses. Dillon (2009) reported that although precise accounting was somewhat flawed, more than 60 percent of students enrolling at two-year colleges, and 20 percent to 30 percent at four-year colleges, took remedial courses.

Despite the limitations in mathematics access for many Black students, mathematics literacy has and will continue to be a necessary skill for obtaining opportunities beyond high school that are both academic and career oriented. Obtaining a basic level of mathematics literacy has even become a greater predictor of income today than it was decades ago (Carpenter & Bottoms, 2003). As the work towards improving mathematics literacy for Black students, and all students for that matter continues, some scholars have suggested another way students can engage in mathematics; establishing a community where students are excited about doing mathematics and where students can take a more active role in the teaching and learning of mathematics with their peers.

Research Questions

The purpose of this study was to examine how the experiences of African American college mathematics literacy workers (CMLWs) and high school mathematics literacy workers (MLWs), within a community of practice namely the Young People's Project (YPP) Chicago, influence the identities they have and inform how they categorize numbers used in the Flagway Game. I also examined what goals CMLWs and MLWs had when working in their communities and the value that they saw in carrying out this kind of mathematics literacy work. This study was guided by the following research questions:

1. What identities do African American college mathematics literacy workers and high school mathematics literacy workers have of the Young People's Project Chicago, in the context of the Flagway Game training?

    a. What led African American college mathematics literacy workers and high school mathematics literacy workers to participate in the Young People's Project Chicago?

    b. What role do African American college mathematics literacy workers and high school mathematics literacy workers see themselves having in their local communities?

2. What are the mathematics strategies used by African American college mathematics literacy workers and high school mathematics literacy workers in number categorization of the Flagway Game and their understanding of these number concepts?

Rationale for the Study

My goal in conducting this study was to investigate CMLWs and MLWs of the YPP Chicago, a community of practice, within the context of their mathematics literacy workshop training. I wanted to understand what aspects of their identities were shaped as they engaged in the training and through reflection of their past and present work implementing a mathematical game, called the Flagway Game.

Despite the widespread awareness of the Algebra Project and the YPP among mathematics educators, there are only a few studies that have examined various aspects of their efforts. These studies have focused on the historical development of one research site in Chicago (N. Cobb, 1994), AP's community development initiatives (Sanders, 1995), an African American program for boys (Nelson, 1997), AP's impact on student achievement in mathematics (Adair, 1996), the impact and effectiveness of the AP's curriculum in an urban high school in Jackson, Mississippi (Davis & West, 2000, 2004a, 2004b), and how members of a community define and address inequities in mathematics classrooms (Davis, West, Greeno, Gresalfi, & Martin, 2007).

Furthermore, there is little research on the work of YPP as an organizing tool for mathematics literacy and for young people learning mathematics. Educators have documented the development of YPP in Jackson, Mississippi (R. P. Moses & Cobb, 2001), and addressed the importance of their work from a social justice perspective at a Chicago outreach site (Gutstein, González, & Masionette, in press). However, YPP remains an underresearched area in mathematics education offering a fruitful area for inquiry. YPP contributes new knowledge to mathematics education in a variety of ways. Studying YPP reveals the complexity in mathematical content of the Flagway Game and the activities that young people engage in. Studying YPP also offers new perspectives on communities of practice that young people engage in and the commitment they make to community outreach work. Finally, YPP sheds light on the complexities of identity and the changing role that young people take on within these social contexts.

Why choose CMLWs and MLWs of the YPP Chicago? I decided to focus on CMLWs and MLWs of the YPP Chicago because the organization met two major criteria of this study. First, out of all of the YPP national sites, this one had the most developed outreach program. Second, I wanted the opportunity to work with a diverse student population and select participants from a large sample of CMLWs and MLWs. The YPP Chicago offered me this opportunity, not to mention the chance to visit multiple sites where trainings occurred.

Significance of the Study

Current mathematics education reform efforts, mathematics educators, policymakers, curriculum developers, and mathematics teachers are investigating new approaches for improving student learning through professional development and other innovative teaching strategies. Mathematics reform efforts have looked broadly at change with the focus on teachers and the way they teach specific mathematics curriculum. Studies have addressed teachers' belief and how they can change their practice in classrooms (Senger, 1999). Studies have also looked at the effects of reform-based instruction on student outcomes (Baxter, Woodward, & Olson, 2001; Schoenfeld, 2002, Thompson & Senk, 2001; Van Haneghan, Pruet, & Bamberger, 2004). Rarely if ever are youth-led initiatives included as part of the reform conversation (Wilson & Corbett, 2007) in general, and as a strategy for change in schools to improve mathematics literacy in particular.

This study contributes significantly to mathematics education in three unique ways. First, YPP is the first program of its kind conducting youth development and youth-led mathematics initiatives in underserved communities with the goal of systemic change in mathematics education. Second, this study takes a look at CMLWs and MLWs within a community of practice of young people and what identities they have within this context. Studying communities of practice is an emerging area of inquiry in mathematics education. Finally, this study contributes to the existing research by giving voice to CMLWs and MLWs who come to mathematics literacy work with a primary objective of creating change in their community by helping children learn mathematics in a unique way. Giving voice provides CMLWs and MLWs with the opportunity to speak for themselves about their experiences rather than being spoken for by others. Studying a youth-led initiative of YPP serves as an exemplar of what happens when mathematics literacy workers are able to take ownership of mathematics with the purpose of improving their own understanding as well as the mathematical experiences of others. My main focus in exploring the above research questions was to understand how CMLWs and MLWs see themselves and the understandings of numbers they extrapolate from their use of the Flagway Game. I also wanted to study how the YPP experience contributes to the identities they formed.

Limitations to the Study

This study is limited to the CMLWs and MLWs of YPP Chicago at one Flagway Game Workshop training. Researching one workshop training limits the ability to generalize across various sites in Chicago and at other YPP sites throughout the country. Because activities at each training site were unique, there may be other factors that influenced identity at other sites in Chicago and at other YPP sites around the country not addressed in this study. I sought to conduct an in depth study on identity and mathematical understandings of CMLWs and MLWs; so the number of participants used in this study is also a limitation. Although a larger sample size may have provided more generalizable results, the small sample size allowed me to gain an in depth perspective on what identities CMLW and MLWs had and how their understanding of numbers in Flagway was enhanced. Because of participant characteristics, this study is also limited to their age and experience in YPP.

Definition of Terms

Throughout this report, several acronyms and terms are used repeatedly. For the purpose of clarity, these acronyms and key terms are defined as follows:

- *Abelin Preparatory High School* – Pseudonym; location of MLW Flagway workshop training and high school attended by two of the participant
- *Agent of Change* – Someone who purposely works toward creating some kind of social, cultural, or behavioral change in society or in others through his or her work or actions
- *Algebra Form* – An algebraic representation, with variables, used to symbolize or stand in for numbers used in a mathematical expression

- *AP* – the Algebra Project
- *CMLWs* – College Mathematics Literacy Workers
- *CMLW Flagway Game Workshop Training* – Facilitated by YPP instructors, CMLWs learned how to facilitate workshop training, play the Flagway Game, and use mathematics activities with MLWs
- *Communities of Practice (CoPs)* – A community of practice is a collective group, unified by common interests where members interact regularly in order to create and improve what they learn and share over time
- *Composite Number* – A whole number greater than 1 that has more than two factors
- *Confident Doer of Mathematics* – An individual who came to YPP confident in his or her ability to do mathematics
- *Even Number* – Any integer that can be divided by 2 without leaving a remainder
- *Factor* – Any of two or more numbers multiplied together to form a product
- *Factor Tree* – A tree-like diagram used to find the prime factorization of a positive integer greater than 1
- *Identity* – Viewed from a situated perspective, it is a negotiation between learners and the various social contexts in which they participate in that influence how they view themselves
- *Increasingly Confident Doer of Mathematics* – An individual who demonstrates a sense of confidence or willingness to do mathematics that developed during the project
- *Mathematics Literacy Workers* – College and high school students in YPP that did mathematics literacy work
- *MLWs* – High School Mathematics Literacy Workers

- *MLW Flagway Game Workshop Training* – Facilitated by a YPP instructor and CMLWs, MLWs learned how to facilitate workshop trainings, play the Flagway Game, and use mathematics activities with elementary students
- *Multiple* – A multiple of an integer is the product of that integer and another integer
- *New University* – Pseudonym; university attended by two of the study's participants
- *Number Sense* – The ability to work with and understand numbers and their relationships, flexible mental computation, quantitative judgments, and how numbers are affected by mathematical operations
- *Odd Number* – Any integer that cannot be divided evenly by 2
- *One Who Preserves* – Someone who continues to persist in or remain constant to a purpose, idea, or task in the face of obstacles or discouragement
- *Outreach Sites* – Elementary schools where CMLWs and MLWs engaged children in mathematics activities to support them learning and playing the Flagway Game
- *Prime Factors* – Positive prime integers that divide into that integer evenly, without leaving a remainder
- *Prime Number* – A whole number greater than 1 that has only two factors: 1 and itself
- *Role Model* – A person who serves as an exemplar of positive behavior in one or more contexts
- *Student Voice* – Giving students a legitimate opportunity to explicitly address their concerns about schools and play an active role in changing how schools function
- *Supporter of Others* is defined to be a person who contributes to the fulfillment of a need or furtherance of an effort or purpose.

- *Training Hubs* – The six sites in Chicago where Flagway Game workshop training took place
- *Trajectory* – A continuous motion of coherence through time that connects the past, the present, and the future; critical in identity formation since renegotiation occurs throughout the course of an individual's life (Wenger, 1998)
- *YPP* – the Young People's Project
- *YPP Instructor* – Former CMLWs that assisted in conducting CMLW and MLW training and supported mathematics literacy workers

CHAPTER 2

REVIEW OF LITERATURE

> Just because you don't see change the way you want it doesn't mean that a change didn't happen. Or just because you are not affecting community the way you think community should be affected doesn't mean that an [effect] didn't happen. (Naomi, College Mathematics Literacy Worker, 2007)

When young people are actively engaged in activities that affect change through forms of mathematical teaching and learning, this engagement enables their own learning and strengthens their identities. This review of literature is organized into five sections: (1) background on the Algebra Project and the Young People's Project, (2) student involvement in school change, (3) critical race theory and education and (4) communities of practice, learning, identity, and mathematics in a social context and (5) research on functions and decompositions. The first section provides a summary of both the AP and the YPP. In this section, I also include the importance of Chicago as a race-place context. The second section reviews the emerging literature on student involvement in school change, and includes a brief historical overview. I discuss the importance of including student voice in school change and research that supports this inclusion is then summarized. The third section provides an overview of critical race theory (CRT) and how its relevance in the field of education. I also include studies that have used the CRT in giving voice to contest race and achievement of Black people. The fourth section I provide a discussion on communities of practice, with emphasis given to the modes of belonging and the processes of identification and negotiability in identity formation. I review literature on mathematics, learning, and identity within a social context. I also provide the usefulness in discussing mathematics and identity in the social contexts of learning. Finally, in the fifth section, I include literature that discusses students' understanding of functions and decomposition.

The Algebra Project and the Young People's Project

The Algebra Project

The Algebra Project (AP) is a national initiative, rooted in the U.S. Civil Rights Movement that is carried out in schools and after-school programs. The main purpose of the AP is to improve the mathematics literacy of young people of color underserved by existing education reform efforts in order for them to gain political and economic power and access to opportunities. As R. P. Moses and Cobb (2001) describe, "The Algebra Project is first and foremost an organizing project – a community organizing project – rather than a traditional program of school reform….Like the civil rights movement, the Algebra Project is a process, not an event" (p. 18). AP's goals are accomplished through mathematics curriculum materials development, teacher training and support, youth mathematics literacy development, and school-community partnerships. For more than two decades, AP has received national attention for its mathematics reform efforts in inner city and rural schools (R. P. Moses, 1994; R. P. Moses & Cobb, 2001; R. P. Moses, Kamii, Swap, & Howard, 1989; Silva, Moses, Rivers, & Johnson, 1990).

Founded in 1982 in Cambridge, Massachusetts, by civil rights activist Robert Moses, AP has two main goals. The first is "to increase the proportion of students who complete algebra successfully in late middle school or high school and enter college preparatory studies" (Davis & West, 2000, p. 1). The second goal of AP is the development of mathematics literacy among disenfranchised students in urban and rural communities. In response to issues surrounding how algebra is taught to Black students of low socioeconomic status (SES), AP works to develop mathematics proficiency through an experience-based approach to learning and pedagogy.

AP's curriculum combines inquiry and experiential learning, which is mathematics emerging from human experience. Mathematics is also made accessible by using real-life situations, like a bus or train ride, and African drumming because they embody rich mathematical concepts. Through the process of mathematizing these situations or events, students are encouraged to actively engage in mathematical discourse by using their everyday language for talking about mathematical concepts. This discourse leads to a focus on important mathematical features about the event and to the process of symbolization. By actively engaging in the mathematics discovery process, students encounter complex mathematical ideas that they learn to work through.

As in the civil rights era, when voting was identified as a requirement for citizenship, AP has identified new criteria for citizenship in today's society: mathematics literacy, but more important, accessing algebra. Our society has grown increasingly competitive and complex, and students residing in poor, marginalized communities are confronted with the challenge of meeting educational demands at an especially earlier age. Consequently, the ability of students in these communities to develop mathematics literacy and proficiency in algebra and strengthen their prerequisite knowledge for algebra becomes even more imperative. Although the AP started to address the importance of algebra as early as the mid-1980s, the results of national studies such as the Third International Mathematics and Science Study (Mullis, Martin, Beaton, Gonzalez, Kelly, & Smith, 1998), underscore the need for U.S. schools to strengthen their secondary curriculum and build the foundation of mathematics literacy for all students in earlier grades.

Algebra has long been seen as a gatekeeper (Chappell, 1997) to higher-level mathematics courses and opportunities. Adequately preparing marginalized students to pass through the gates has become the main mission of AP's work. Chappell argues:

> Preparing students to enter the gate to algebraic thinking contributes to minimizing the differences in mathematics-course participation and achievement that have long existed between males and females and different racial and ethnic groups. To close these gaps in achievement, we need to open the gate to algebraic thinking. (p. 267)

In light of this increased demand for mathematics literacy and proficiency, AP works in urban and rural communities to make algebraic ideas more contextual, meaningful, and realistic. Like the National Council of Teachers of Mathematics (NCTM, 2000) *Principles and Standards for School Mathematics*, AP promotes constructivist (P. Cobb, 1994; Clements, 1997; Clements & Battista, 1990; von Glaserfeld, 1983) ideas for student learning and nontraditional approaches to teaching. In *Radical Equations*, R. P. Moses and Cobb (2001) describe how they use the constructivist approach in the AP curriculum to provide students with everyday mathematical experiences.

In the late 1980s, the curriculum development work of AP targeted students in middle school, where many of them were exposed to algebraic concepts and thinking for the first time. This was called the Algebra Project Transition Curriculum. AP was awarded the Instruction Materials Award by the National Science Foundation (NSF) to build partnerships with research mathematicians. The NSF award enabled Bob Moses to make the curricular shift to develop materials for secondary mathematics classrooms. The award also provided AP with credibility in the mathematics community. The Transition Curriculum was not used in schools after the early 1990s due to the increased demand for high stakes testing.

In addition to offering the traditional algebra course, some middle and high schools also adopted the AP curriculum as an alternative way of introducing algebra to underserved student populations. Students voluntary opted out of traditional algebra classes and enrolled in an AP class with an agreement to take the course 5 days a week for an hour and a half during a block schedule. AP-trained teachers facilitated the AP classes for the entire school year. On completion of a year of algebra with AP, students entered the next level of mathematics at their respective schools. At only one site, Lanier High School, have AP students gone through an entire 4-year mathematics sequence using AP-developed curriculum materials. Other schools have yet to adopt this format. Since its inception, AP's curriculum has reached over 40,000 students in 13 states, including California, Massachusetts, Mississippi, Illinois, and New York, as well as 28 school districts (Algebra Project, 2006).

The AP's grassroots approach to educational change positions it to play a significant role in education reform in general and mathematics reform in particular. Robert Moses and his work in the AP have also helped to pioneer a new grassroots effort, the Quality Education as a Constitutional Right (QECR) movement. The QECR movement began in 2005 at Howard University, where scholars, activists, parents, students, and other community stakeholders came together to discuss "how to ensure that a quality education is guaranteed to all [of] America's children" (QECR.org, 2008, QECR: History). The primary goal of QECR is to build consensus with political leaders and community stakeholders in developing a constitutional amendment guaranteeing a quality education as a *civil right* for all children so that they can gain access to full citizenship in today's society.

AP continues to work in rural and urban communities. The youth-affiliated organization, the Young People's Project, also works in these communities to improve the mathematics outcomes of students through community outreach efforts.

The Young People's Project

The Young People's Project (YPP), is a youth-led organization that is an outgrowth of, and in partnership with the Algebra Project. The YPP was founded in Jackson, Mississippi, in 1996. YPP is a youth-empowerment and after-school mathematics initiative created by an alliance of Black students who were AP graduates of Sam M. Brinkley Middle School in Jackson, Mississippi. Brinkley AP graduates wanted to take an active role in their community by preparing youths to become more mathematically proficient. YPP was "founded on the belief that there is work that young people can and must do to change the conditions of their lives and that math literacy work was a good place to start" (Tyyp.org, 2009, YPP Math Literacy + Social Change: History). They also believed this work was necessary, because Mississippi remains one of the most economically depressed and poorest performing states in the nation when it comes to education. Performance of Black schools also remains at the bottom in the state (Southern Education Foundation, 2006). According to National Assessment of Educational Progress (NAEP) data, Mississippi students are far behind students in most other states in every grade and subject area. Specifically in mathematics, fourth and eighth grade students in the state scored at least one grade lower than the average student in the nation (NCES, 2005b). Quoted in Robert Moses' *Radical Equations,* Mae Bertha Carter, a civil rights activist, talked about the failure of Mississippi schools to adequately prepare children:

> The way to control Black people or anybody is to keep them dumb. You keep them dumb and you can control them. Back in slave time they catch you reading and they would whip you. Education, that's the goal. Getting the knowledge and understanding. If you are uneducated you don't know nothing. You don't know what's going on around you. So what they're doin' is handicapping kids. These school systems ain't doing nothing but handicapping these children. (Moses & Cobb, 2001, p. 134-5)

YPP has three main objectives. The first is to use mathematics literacy to develop youth leaders and organizers who would radically change the quality of education and life in their communities (O. Moses, 2006). The second objective is to develop young people as facilitators, mentors, and advocates for mathematics literacy. The third objective is to assist a target population of AP students and non-AP students to successfully complete algebra by eighth and ninth grade and to enter a college preparatory mathematics sequence in high school. YPP works to achieve these objectives through the development and implementation of mathematics games and activities in schools. Addressing these objectives is different from city to city because YPP's scope of activities varies across sites. The work of YPP is tailored to meet the demands of the community it serves.

Members of both AP and YPP believe that young people in today's society must play an active role in helping students achieve mathematics literacy (R. P. Moses & Cobb, 2001). Moses also believes that young people need to be inspired to fight for their own liberation. Like the AP, which is guided by the belief that all children, regardless of their racial, cultural, or socioeconomic background, can learn algebra as well as other areas of mathematics, YPP develops and prepares college and high school students, who are known as college mathematics literacy workers (CMLWs) and high school mathematics literacy workers (MLWs), respectively, to market their mathematics skills in both after-school programs and through an AP network composed of activists, educators, parents, and teachers. CMLWs and MLWs have presented their work at regional conferences of the NCTM and at the Mathematics Science Research Institute in Berkeley, California, which has given them the opportunity to demonstrate the materials they use in their community work to the broader mathematics and mathematics education community.

After successful preparation in training workshops by YPP instructors, CMLWs and MLWs lead their own training programs for new students, which are coordinated weekly in schools. CMLWs and MLWs organize homework help centers, training sessions, and summer institutes. At several YPP sites throughout the country, supplemental mathematics curriculum materials are developed and used in AP classrooms and in workshops where the mathematics skills of CMLWs and MLWs are demonstrated to peers, mathematics teachers, and parents. Omowale Moses, son of Robert Moses, a founding member, and the executive director of YPP, further explained the mission of the organization:

> The goal of the YPP training process is to enable MLWs to develop math skills in a way that builds a culture of youth leadership, ownership, and teamwork. We also attempt to produce young people who can effectively teach, mentor and tutor other students. (Typp.org, 2008, About the Young People's Project)

The organizing initiative of the YPP follows the legacy of the Student Non-Violent Coordinating Committee (SNCC), a grassroots student-led organization during the civil rights movement (Bond, 2000; Carson, 1981). At the forefront of the civil rights movement were young people in SNCC who played an integral role in changing the racial, economic, and educational conditions in their communities. College and high school students organized voter registration drives, marches, and sit-ins, demanding to local, state, and national officials that people of color deserved voting rights, access to opportunities, and a legitimate place in society. YPP continues this tradition by organizing young people to demand their right to a quality mathematics education not only through public demonstrations (Schoettler, 2004), but by working with students to achieve the accessibility of mathematics in underserved communities.

The YPP was created by young people for young people. In the spirit of youth leadership, YPP serves as a tool for inspiring students to play an active role in the mathematics education of others while empowering their peers. Similar to the way that sharecroppers fought for their own voting rights in the 1960s, YPP gives students of color ownership of learning mathematics. Furthermore, YPP enables students to make the argument on their own terms, through their outreach work, that mathematics is important in today's society. The statement that follows summarizes how the YPP hopes to shift how young people begin to see themselves:

> We want young people to harness the power of their culture to work for them and not against them. We want young people to challenge the dominant cultural logics that help to marginalize them. We want young people to reject any cultural expectations that limit who they can and should want to be. YPP wants to make it cool for young people to learn and share what they know…. Young people need to broaden their cultural expectations about what's cool, what's acceptable, and what's respectable -- if we can celebrate each other for being young athletes and hip hop artists we can celebrate each other for being young scholars, organizers, and orators. (Young People's Project, 2008, p. 3)

Over the years, YPP has expanded to several cities, including Greater Boston and Chicago, and is developing sites in Miami, FL; Detroit, MI; New Orleans, LA; Oakland, CA; Rochester, NY; Petersburg, VA; and Yuma, AZ. For my study, I selected YPP Chicago.

YPP Chicago. YPP Chicago was started in the summer of 2002 through a partnership with the Chicago Public Schools Mathematics and Science Initiative (CMSI) and After-School Matters (ASM). CMSI is a comprehensive strategic plan to improve mathematics and science instruction in all of Chicago public schools. ASM is a Chicago-based non-profit organization that offers out-of-school opportunities to city teens. Maintaining an office at ASM headquarters, YPP partners with the two programs to operate training hubs throughout the city of Chicago for the development of CMLWs and MLWs.

Each of the training hubs is affiliated with one of three local institutions of higher learning: DePaul University, the Illinois Institute of Technology, and the University of Illinois at Chicago. The goal at each training hub is to develop and prepare a team of CMLWs and MLWs to conduct training programs in Chicago public schools, churches and community organizations for middle and elementary students, parents, and community members. There are six training hubs in Chicago: four high schools and two universities. YPP Chicago has prepared over 200 high school and 50 college students to conduct math literacy workshops and community events. CMLWs and MLWs carry out math literacy workshops in 20 sites in the North, South, and Westside communities of Chicago (O. Moses, 2006).

YPP Chicago seeks to develop mathematics literacy in algebra for eighth and ninth graders and develop number sense with elementary students in Grades 3 to 6 through the Flagway Game program. The program engages students in mathematics numeracy through mathematically rich games and activities. This approach is taken to “radically change how and what students learn about their first 150 numbers” (O. Moses, 2006, p. 33). Furthermore, because of the competitive aspect of the Flagway Game it “seeks to create an opportunity for students in Chicago to learn and celebrate learning math, in the same way that they learn and celebrate learning basketball” (p. 26). Further, although there are several state-funded mathematics initiatives in Chicago, many are book and worksheet focused, geared toward students taking and passing the Illinois State Achievement Test (ISAT). Consequently, Chicago youths are not afforded many opportunities to learn mathematics outside of a school context like YPP.

The Race-Place Context, Chicago, and Black Educational Disenfranchisement

Scholars have highlighted the importance of foregrounding the interconnectedness of *race and place* in recent literature (Bullard, 2007; Frazier, Florence, & Eugene, 2003; Morris & Monroe, 2009). Place should not be separated from an analysis of race in the United States because each place is critical (Morris & Monroe, 2009) and comes with unique issues. Scholars argue that in order to fully conceptualize and understand educational achievement in general, and a Black educational experience in particular, the context of place and the cultural, historical, racial, political, and economic distinctions that each brings must always be considered to gain a deeper and more holistic perspective (Morris & Monroe, 2009). In my effort to set the stage, in this section, for a brief yet broader discussion of geographical location and its influence on African American schooling and achievement, I consider Chicago, as a race-place context for YPP Chicago.

Chicago is inextricably linked with the South in many ways. Chicago was the site of a major population shift of Blacks from southern states like Mississippi as early as the First World War. Black migrants flocked to the urban North in search of better jobs and a better way of life. The exodus from the South is known as the Great Black Migration, and it began as early as 1910, lasting until the early 1970s (Drake & Cayton, 1962). Black migrants arrived to Chicago from southern states hopeful of a new life and what the big city could offer their children with regard to education. However, many were met with racism and discrimination from Whites, which paralleled Jim Crow laws in the South. Many Blacks were systematically excluded from exercising their civil rights when trying to gain access to basic life necessities like public accommodations and services, jobs, adequate housing, and quality schooling for their children. Furthermore, in Chicago, Whites demarcated strict color lines, which bounded where Blacks could and could not reside and go to school. Consequently, Blacks were restricted to densely populated districts known as enclaves. Some enclaves later became slums and ghetto neighborhoods that were difficult to relocate out of (Spear, 1967). Because of systemic racial discrimination and economic deprivation, many Blacks in Chicago experienced continuous disenfranchisement. These events, among others, laid the foundation for a biracial Chicago, a White one and a Black one. These two Chicagos still exist today.

Although Chicago has been a major urban center of media, business, and political opportunity for Blacks, it fares poorly in comparison to other major cities when it comes to educational achievement of students, particularly in mathematics. According to a recent report using TIMSS assessment data, the Chicago Public Schools performed significantly lower on mathematics achievement tests as compared to other school districts in Illinois and other states around the country (Wright et al., 2003). This distinction is important since the Chicago Public

Schools (CPS) is the largest school district in the state and third largest school district in the nation. CPS is composed elementary schools, high schools, and charter schools (e.g., elementary and high school). The racial breakdown of students attending CPS was approximately 46.2% of African Americans, 41.2% of Latinos, 8.9% of Whites, and 6.6% of other ethnic groups. In 2007, the Chicago Public School graduation rate was approximately 55.1% citywide, with only 50.1% of Black students graduating. Moreover, approximately 84.3% percent of all students attending CPS were from low-income households (CPS, 2009). Furthermore, Chicago had the sixth highest Black poverty rate among 23 major cities around the nation.

The Chicago area ranks fourth in the nation in African American and White school segregation. Segregation is seen mostly in urban communities where large concentrations of Black people reside and attend schools. Massey and Denton (1993) define segregation as "the general tendency of blacks and whites to live apart" (p. 74). They conceptualize segregation quantitatively along five dimensions: unevenness, isolation, clustering, concentration, and centralization (Massey & Denton, 1988). They further assert that a metropolitan city is considered to be hypersegregated if it is "very highly segregated on at least four of the five dimensions at once" (Massey & Denton, 1993, p. 74). In a study on U.S. metropolitan areas with large Black populations, according to their estimates, Chicago was identified as a hypersegregated city along all five dimensions.

African Americans continue to be the most segregated racial/ethnic group in the United States (Bullard, 2007). The issue of segregation or hypersegregation becomes a critical issue when considering its connection to school funding (Carey, 2003). Illinois ranks forty-ninth nationally in the amount of educational funding provided by the state for each student. Funding disparity ranges from $18,225 per student in predominantly White areas of the state to $6,678 per student in areas like Chicago, where predominantly non-White students attend school (Center for Urban Research and Learning, 2006). These differences in spending per student reflect explicit racial education gaps. Discrepancies in funding affect the types of educational resources that are available to all students, educational quality, and achievement. These discrepancies provide some explanation for the racial inequities that continue to exist in Chicago schools today. When all students are not afforded equitable resources for a quality education, that limits how and where they participate in society. Foregrounding Chicago as a race-place context provides impetus for discussing YPP in Chicago. The emergence and work of YPP Chicago is a response to and an effort towards combating some of the inequities that exist among Black disenfranchised youth.

Student Involvement in School Change

Students' Historical Involvement in School Change

Encouraging students to play an active role in their education and school reform movements is not an uncommon phenomenon. Historically, students have exercised their right to participate in the decision-making process of what happens in schools and in classrooms (Cusick, 1973; deCharms & Roth, 1976). Inclusion and participation were a legacy of civil rights movements and evident in student power movements of the 1960s and 1970s. During that time, the involvement of students in school change efforts was largely around the issue of democracy and political involvement. Students actively questioned the status quo and carefully worked to transform the educational and political conditions in schools, universities, and their communities (Carson, 1981; Williamson, 1999). Since that time, the role of students in the decision-making process of school change has diminished considerably. Students' voices have become even more silent in schools, where young people experience alienation, tracking by ability and age, and students have a conception of themselves as clients as opposed to learners. This has created a distance between students and teachers (Costello, Toles, Speilberger, & Wynn, 2000; Mitra, 2004; Nieto, 1994; Pittman & Wright, 1991; Soo Hoo, 1993).

Levin (2000) explains that in the mid 1970s there was a shift in the idea of student involvement in school decision-making to students taking a more passive role in schools. Students have become the "objects" of change, "objects to be worked upon rather than actors to be taken seriously" (p. 164). Fullan (1991) also gives a summary of how students are now viewed and its relation to school change. He writes:

> When adults do think of students, they think of them as the potential beneficiaries of change. They think of achievement results, skills, attitudes, and jobs. They rarely think of students as participants in a process of change and organizational life. (p. 170)

More recently, the discussion of students' involvement in school change is resurfacing in education literature as a necessary requirement to any reform effort's effectiveness (Fielding, 2001). Even with the necessity and recent attention to improve student performance and outcomes in areas like mathematics, students are still rarely given a role in school reform in the United States, "despite the fact that many reforms are intended to create more equitable and engaging educational programs for students" (Mitra, 2004, p. 652).

Although the literature in this area was quite limited, I decided to include theoretical arguments and studies that spoke to the importance of student voice in the school change process along with studies that focused on various aspects of student participation in actualizing change. In doing so, my objective was to understand how student voice has been *actualized* in schools and what aspects of student participation have been emphasized in the literature. I also wanted to review literature that focused on how student voice has been "conceptualized" and perceived.

Importance of student voice in school change. When students are allowed to voice their opinions about what happens in schools, it gives them the opportunity to share their views about problems and come up with real solutions. More importantly, when students who are disengaged in the educational process are asked their opinions about school improvement, they are given a sense of purpose and promise (Nicholls & Thorkildsen, 1995). There is mutual benefit to both teachers and students when this kind of work is done. As Erickson and Schultz (1992) suggest, "The absence of student experience from educational discourse limits the insight of educators as well as that of students" (p. 160).

Lodge (2005) urges a critical examination of what is meant by student voices and involvement. When we decide to speak for some, we are unintentionally leaving out others. Some scholars also argue that if students play a more active role in shaping what school reform looks like, that will greatly improve student outcomes and reform efforts (Levin, 2000; Mitra, 2004). Johnston and Nicholls (1995) point out that teachers often come into contact with students who try to develop their own authority and are yearning for their voices to be heard in schools. Recent literature suggests that giving students authority by including them in school change efforts can serve as a vehicle for improving teaching, curriculum, teacher-student relationships, student assessment, and teacher training (Fielding, 2001; Mitra, 2003; Oldfather, 1995; Rudduck & Flutter, 2000; Soo Hoo, 1993). It has also been claimed that improved behavior, better staff-student relationships, higher attendance, and higher levels of achievement have all been attributed to students' inclusion in the decision-making process in schools (Biermann, 2005). Nieto (1994) also underscores the importance of student voice by noting its scarcity in school policies and practices. She writes:

> One way to begin the process of changing school policies and practices is to listen to students' views about them; however, research that focuses on student voices is relatively

> recent and scarce. For example, student perspectives are for the most part missing in discussions concerning strategies for confronting educational problems. In addition, the voices of students are rarely heard in the debates about school failure and success, and the perspectives of students from disempowered and dominated communities are even more invisible. (p. 396)

To help students and other stakeholders find a meaningful role in school reform, Goldman and Newman (1998) offer strategies on how to get them started in improving schools. Students, in particular, are able to define reform needs as well as the opportunity to put many of them into practice. Furthermore, diverse student populations are included in school processes.

Scholars interested in the issue of student voice and student involvement have asked, “What role does student voice have in the decision making process of school change or reform?” In response to this question, Lincoln (1995) suggests that the role of student voice is embodied within three distinct contexts in which we place students: a social and legal context, a scientific context, and a political context. In the social and legal context, student voice is a necessity that reflects the long history of civil rights efforts in this country. Unlike the past, where the rights of children were not considered, today’s orientation brings awareness to many that children are indeed citizens and benefactors of the future and that their ideas should be heard and respected. In the scientific context, attention to student voice brings an understanding of how learning occurs. Schools are spaces where students make sense of their world and some of the most influential sites for learning. In this way, attention to how students actively formulate their realities in the social world offers new promises and opportunities for learning. Students are also placed in a political context as well. Lincoln argues that the purpose of education in this country has been for democratic participation even though we have not achieved that purpose effectively. The role in student voice is to support a “democratic, just, and economically viable and prosperous society [that] requires active participation and critical thinking skills far beyond what many of our students experience in school" (p. 89).

Corbett and Wilson (1995) took a slightly different approach in their discussion of the importance of students in the changing process of reform. They argued that student participation is not independent of reform. We must consider the role of students in the reform process, not separate from it. If we have the expectation that students should change, then our expectations of them should change as well.

Although there is a growing body of research that argues for the merits of student voice, there are very few studies that have actually examined how student voice is used to create change in schools. Although some of these studies have been conducted in the United States, many have been conducted in other countries, like Australia, Canada, and the United Kingdom. The focus of these studies has been on rights and empowerment of students as in the past, particularly during the U.S. Civil Rights era. But current attention is on the effects of student voice and involvement on student outcome and school reform, with a particular emphasis on the various ways student voice was sought (Mitra, 2004).

Research on Student Involvement in School Change

Pupil participation and school change. Rudduck and Flutter (2000) argue that pupil participation and perspective are important aspects of changing curriculum and instruction. The relevance of curriculum is usually an adult view of what is important rather than a pupil view of what young people find meaningful. In interviews conducted with pupils in primary and secondary schools in the United Kingdom, they found that pupils were interested in "changing the structures that cast them in a marginal role and limit their agency" (p. 84). Rudduck and

Flutter's interviews allowed them to construct a model of pupils' commitment to learning and their identity as learners. They argue:

> The regimes of school, which embody values operating through structures and relationships, shape pupils' attitudes to learning and their view of themselves as learners. The more that the regimes are changed to reflect the values that pupils call for (intellectual challenge, fairness, etc.), the stronger pupils' commitment to learning in school is likely to be. (p. 85)

The model that Rudduck and Flutter (2000) offers is interesting because it shows what structures need to be in place or what structures need to "change" within a certain context to realize the pupils' commitment to learning. For example, certain structures that support student participation as opposed to others.

Schratz and Blossing (2005) provide their individual perspectives on pupil participation in school change in a two-part article. Schratz argues that pupils should be able to make decisions about school change because it directly affects them. Moreover, pupils are capable because they are required to make decisions about other important aspects of their lives every day. Schratz believes that in order for students to be effective in this kind of work, they should be equipped with the right literacy. Literacy is described as the everyday decisions young people are required to make to help them learn about life and their competency in doing so. He also argues that the power structure in most schools does not promote pupil participation. In order for student involvement to be effective and taken seriously, our view of teaching and learning must shift.

Blossing holds similar views to those of Schratz and contends that pupil participation is a key component to ensure any implementation effort in schools. Blossing argues that pupil involvement is a matter of democracy because an important aspect of a decision process is organizing "various views of interest" within a dialogue.

Levin (2000) offers a pragmatic line of reasoning for greater student participation that is based on five factors:

> 1. Effective implementation of change requires participation buy-in from all those involved, students no less than teachers;
> 2. Students have unique knowledge and perspectives that can make reform efforts more successful and improve their implementation;
> 3. Students' views can help mobilize staff and parent opinion in favour of meaningful reform;
> 4. Constructivist learning, which is increasingly important to high standards, requires a more active student role in schooling;
> 5. Students are the producers of school outcomes, so their involvement is fundamental to all improvement. (pp. 156-157)

Student voice in school change. In the United Kingdom, a 3-year study project, Students as Researchers, was conducted at Sharnbrook Upper School, where students adopted various roles throughout the project to address specific issues within their high school (Fielding, 2001). In Year 1 of the study, a student cohort of mixed age and gender took on the researcher's role to identify important issues and problems that needed to be addressed from daily interactions with teachers and students. Student researchers were then asked to make recommendations to be shared with their peers, staff, and governing bodies in the school. In Year 2, Students as Researchers continued in the same way as the year before, but others within the cohort became student consultants and offered support and their expertise to a new cohort. Year 3 was an extension of the work from the prior year, and the methods of research done during the Students as Researchers project were shared with other schools in the United Kingdom as well as abroad. Fielding reported that to both acknowledge and promote student voice, the degree to which these key components can be demonstrated by students was important. A framework to honor their input had to be in place. The framework considered the following topics: speaking, listening, skills, attitudes and dispositions, systems, organizational culture, spaces, action, and the future.

Students as researchers is discussed elsewhere in the literature as a relatively new approach to research, and there are only a handful of studies that have engaged in this method of inquiry (Alder & Sandor, 1990; Atweh & Burton, 1995; Boomer, 1987; Knight, 1982; Schwartz, 1998; Slee, 1988). In every one of these studies, the main goal was to have students experience the process of research. In addition to the work that Fielding (2001) reported, only two of the students as researchers projects were close to a focus on educational change (Atweh & Burton, 1995; Slee, 1988). Slee conducted a study to identify the educational needs of 13-14 year olds not met by the educational system. Atweh and Burton also conducted a sociological study. It focused on the factors that affect students' choice to remain at school. The study was based on the premise that socioeconomic status influences students' participation in schools.

Student voice efforts have also been connected to youth development outcomes. In a study at Whitman High School, located in a northern California community, the goal was to maximize the opportunities to observe student involvement in the school's reform work (Mitra, 2004). There were two student groups at Whitman that worked in isolation but engaged in student voice activities: Pupil-School Collaborative and Student Forum. The two groups shared similar goals for school improvement by involving students more directly in reform efforts. Student voice efforts included collecting information from students, participating in focus groups, and administering surveys to students who worked closely with teachers to determine the best strategies for school improvement. The findings from the study showed that for students who were members of either group, their direct involvement in school change efforts led to increases in youth development. Youth development in this case was attributed to three qualities: agency, a sense of belonging, and competence. Students from both groups constructed new roles for themselves as change makers in their schools, offered opportunities for the youth at Whitman to cultivate a sense of belonging, and critiqued their environment, where injustices were identified.

Nieto (1994) conducted a study with students from a variety of ethnicities, developing extensive case studies to understand the benefits of multicultural education for students with diverse backgrounds. Students provided their views on a wide range of topics, including school policy and practice, curriculum, pedagogy, and racial discrimination. In interviews students expressed their concerns about representation of their families and communities in their schools. Students also voiced their concern about teachers maintaining traditional practice, despite the fact that they were undergoing a reform in their schools.

In a study at Seacrest High, another high school in northern California, administrators conducted focus group interviews to determine why failing students believed they were unsuccessful in school (Mitra, 2001). Students were able to give a clear rationale for their struggles. Mitra found that many of the reasons that students gave for not performing well in school did not correlate with the rationale given by teachers. Giving students the opportunity to voice their concerns helped the teachers to think critically about the assumptions they made about students, and to take reform efforts seriously.

Another relevant study reported that student voice efforts produced a new identity in students as change makers in their school (Mitra, 2004). One way student identity became salient was by having students engage in conversations about reform and providing a student perspective at professional development training sessions. Elsewhere Mitra (2003) suggests that increasing student voice improves student learning, especially when it is directly associated with changing curriculum and instruction. This claim is also substantiated in Rudduck and Flutter's (2000) work on pupil participation.

The literature speaks broadly about student voice and student involvement in school change. Researchers included students who attended schools where change efforts took place. The studies spanned areas that included student voice in teaching, curriculum, and various policies and procedures, as well as student participation in school change efforts. There were also studies that focused on students being a part of the research process, gathering data on behalf of other researchers. These studies were needed because they focused on students involved in change efforts in some way. However, these studies did not focus on the school change efforts of students in a specific subject, nor did they focus on students making changes to curriculum who were not attending the same school. More important, none of the studies examined students who created intervention programs in schools they did not attend. Finally, I did not find any studies that examined the role that students played in changing what happens in mathematics classes.

Critical Race Theory and Education

Critical Race Theory

Critical race theory (CRT) is an oppositional theory that challenges dominant narratives of widely held hegemonic truths. Through a process of deconstructing why these truths are held, the deployment of CRT creates spaces for new kinds of narratives that have not been considered before. CRT borrows from several theoretical traditions such as law, critical theory, feminist theory, and postmodern theory among others. Critical race theory grew out of legal studies and was first developed in the mid 1970s in response to the failure of critical legal studies (CLS) in addressing race in the legal system. CLS is a well-known movement that explores the way the law conceals culturally accepted norms and standards in society. Crenshaw, Gotanda, Peller, and Thomas (1995) explain that although the early works of CLS were in fact pioneering, the dissatisfaction that many scholars of color had “stemmed from its failure to come to terms with the particularity of race, and with the specifically racial character of 'social interests' in the racialized state" (p. xxvi). Legal radicals gave a critique of liberalism but fail to address how race and racism were deeply embedded in American life (Cook, 1995; Matsuda, 1995). CRT grew out of the work of legal scholars, Derrick Bell, Alan Freeman, and Richard Delgado (Delgado & Stefancic, 2001), who examined the historical centrality and complicity of law in its perpetuation of racism and white supremacy. Cornell West (1995) explains that "critical race theorists, for the first time, examined the entire edifice of contemporary legal thought and doctrine from the viewpoint of law's role in the construction and maintenance of social domination and subordination" (p. xi). In West's view, scholars of color deconstructed the basic assumptions of mainstream liberal and conservative ideology in the legal academy.

In addition to the critique of race in the legal system, CRT also embodies an emancipatory agenda as well. Scholars across disciplines have combined CRT with other critical epistemologies in order to argue for a social justice agenda, which puts issues of race and other forms of discrimination in public discourse (Parker & Lynn, 2002). The emancipatory work that is critical in schools is addressed with CRT and it works ongoing for a change in the current educational structure. CRT gives scholars the space to do the analysis of centralizing race and deconstructing how law upholds white supremacy in schools, with the aim of moving toward equitable and just learning environments for students. Crenshaw, Gotanda, Peller, and Thomas (1995) outline two central interests that CRT addresses:

> Critical Race scholarship differs in object, argument, accent, and emphasis[;] it is nevertheless unified by two common interests. The first [is] to understand how a regime of white supremacy and its subordination of people of color have been created and maintained in America, and, in particular, to examine the relationship between that social structure and professed ideals such as "the rule of law" and "equal protection". The second is a desire not merely to understand the vexed bond between law and racial power but to change it. (p. xiii)

Tenets of Critical Race Theory

There are five main tenets that guide CRT: (a) the permanence of racism, (b) a critique of liberalism, (c) whiteness as property, (d) the interest convergence dilemma, and (e) counter-storytelling and narratives.

Permanence of racism. CRT begins with the idea that racism is "normal not aberrant," a social construction, woven into the fabric of American society. In his groundbreaking book, *Faces at the Bottom of the Well*, Derrick Bell (1992) argues that the legacy of racism in the United States has had an enduring position and that Black people will never gain full access because of it. He goes on to state that:

> Even those Herculean efforts we hail as successful will produce no more than temporary "peaks of progress," short-lived victories that slide into irrelevance as racial patterns adapt in ways that maintain white dominance. This is a hard-to-accept fact that all history verifies. We must acknowledge it, not as a sign of submission, but as an act of ultimate defiance. (p. 12)

CRT analyzes how race is deployed in our daily activities. In other words, it looks at how racist notions are strategically put into action and carried out in everyday life. CRT also analyzes *othering*, which is a way of reifying the positive identity of an individual while stigmatizing an "other." As DeCuir and Dixson (2004) also point out,

> Permanence of racism suggests that racist hierarchical structures govern all political, economic, and social domains. Such structures allocate the privileging of Whites and the subsequent *othering* of people of color in all arenas, including education." (p. 27)

Critique of liberalism. CRT scholars use race as a unit of analysis in understanding the slow pace in changing legal proceedings for people of color in resolving racial inequalities and gaining citizenship. Liberal legal practice, however, supports these slow changes. CRT scholars have posed critiques of three main liberal ideologies: the notion of colorblindness, the neutrality of the law, and incremental change (DeCuir & Dixson, 2004). CRT scholars agree that racism needs “sweeping changes, but liberalism has no mechanism for such change” (Ladson-Billings, 1998, p. 12).

Whiteness as property. Taylor (1998) reminds us “democracy in the U.S. context was built on capitalism” (p. 47). For this reason, America’s capitalistic system has been a challenge to many minorities because of their lack of power and property. Property rights in the United States are entrenched in racial domination. Cheryl Harris (1995) points out that historically, race was not the only means of subjugating Blacks and Indians: “Rather, it was the interaction between conceptions of race and property which played a critical role in establishing and maintaining racial and economic subordination” (p. 277). In a broader historical context, when conceptualizing property, it “embraces everything to which a man may attach a value and have a right,” which places emphasis on legal rights. Historically, property was not thought of just as the right to material objects and an individual’s relationship to those objects. It was also conceived of as “human rights, liberties, powers, and immunities that are important for human well-being including freedom of expression, freedom of conscience, freedom from bodily harm, and free and equal opportunities to use personal faculties” (p. 280). The property functions of whiteness come into being when the law that is in place benefits those holding whiteness with the same privilege granted as those holding property. African Americans in the United States are presented with an interesting predicament as Ladson-Billings (1998) describes: “Not only were they not accorded individual civil rights because they were not White and owned no property, but they were constructed as property!” (p. 15). The economic functions of whiteness as property still exist today. Because whiteness is regarded as the ultimate form of property, many Whites are afforded economic and educational privileges because they possess it. Examples of whiteness as property are disproportionate home ownership, access to bank loans, job opportunities, and quality education.

Interest convergence dilemma. Critical race scholars argue that the primary beneficiaries to civil rights legislation and most legislation for that matter have been Whites. The interest convergence dilemma holds that the interests of people of color seeking equal opportunity "will only be granted when the opportunity being sought converges with the economic self-interest of whites" (Bell, 1980, 1992; Tate, 1993). Tate (1993) adds, "No authorization will be given to remedies sought to promote racial equality for African Americans where the remedy sought threatens the economic or social status of the affluent" (p. 17). To further explicate interest convergence, consider the historical court decision, *Brown v. Board of Education* as an example. Some scholars argue that schools were forced to desegregate not because American society wanted to move closer to racial equality (Balkin, 2002; Bell, 1980; Reid, 2006). Instead, American racial politics had become a source of international liability and embarrassment. If the United States wanted to combat communism, they had to look favorably to the international community and remedy explicit racial inequalities at home.

Counter-storytelling and narratives. The integration of experiential knowledge of people of color is also at the heart of CRT scholarship to "analyze the myths, presuppositions, and received wisdoms that make up the common culture about race that invariably render Blacks and other minorities one-down" (Delgado, 1995, p. xiv). Counter-storytelling gives *voice* to people of color. The meta-narratives of equality, meritocracy, objectivity, and capitalism are still deeply rooted in society and very much a part of schooling; they often go unexamined and unquestioned. CRT utilizes the voice of those that are marginalized to break their silence and challenge dominant discourse. Counter-storytelling gives people of color a chance to describe their own unique oppression within hegemonic structures. When oppressed people are validated through their experiences and stories that counter the dominant narrative, empowerment can be gained. Delgado (1990) also points out "all people of color speak from a base of experience that in our society is deeply structured by racism" (p. 98). Through these experiences, commonalities can be found. Ladson-Billings (1998) also affirms the principal reason that counter-stories are a necessity among CRT scholars: "They add necessary contextual contours to the seeming 'objectivity' of positivist perspectives" (p. 11). Parker and Lynn (2002) further assert that CRT plays an important role because "storytelling constitutes an integral part of historical and current legal evidence gathering and findings in racial discrimination litigation" (p. 10).

Critical Race Theory and Educational Research

Critical race theory has been used by scholars to explicate how race and racism is embedded in our systems of legal practice. Outside of the legal studies, researchers have found great utility of CRT in the field of education. Two notable scholars, Gloria Ladson-Billings and William Tate, are credited with first exploring how CRT could be used in educational scholarship to aid in advancing the field (Ladson-Billings & Tate, 1995). In one of her earlier writings of CRT and education, Ladson-Billings (1998) asserts, "If we are serious about solving these problems in schools and classrooms, we have to be serious about intense study of and careful rethinking of race and education" (p. 22). Ladson-Billings (2000a) also suggests that "although CRT has been used as an analytic tool for understanding the law (particularly civil rights law), as previously noted, it has not been deployed successfully in the practical world of courts and legal cases of schools" (p. 265). Tate (1997b) argues that because race is deeply embedded in American society, it remains "untheorized as a topic of scholarly inquiry in education" (p. 196). Tate also writes "the significance of race in the United States, and more specifically ‘raced’ education, could not be explained with theories of gender or class” (p. 196). Race, gender, and class are usually treated as variables that can be controlled or fixed in research. CRT scholars put race front and center in the analysis of societal structures that impede students from achieving rather than looking at race as a variable factor that can be held constant. Parker and Lynn (2002) explain, “CRT can be used as a tool through which to define, expose, and address educational problems” (p. 7).

Since the initial call by Ladson-Billings and Tate (1995) to foreground race in educational scholarship, CRT has been used in variety of ways. It has been used in educational scholarship to combat dominant narratives of colorblindness by bringing forth voice in understanding the racialized experiences of marginalized racial groups. Such groups are African Americans (DeCuir & Dixson, 2004), Chicanas/Chicanos (Pizzaro, 1998; Solórzano, 1998), and Mexicans (Gonzalez, 1998), to name a few. It has also been used in educational scholarship to advance a critical race pedagogy (Lynn, 1999), investigate non-White children’s experience with racism in school and their community (Masko, 2005a, 2005b), explore how CRT may be used as a methodological tool in qualitative research (Bernal, 2002; Chapman, 2007; Duncan, 2002; Fernandez, 2002; Smith-Maddox & Solórzano, 2002; Solórzano & Yosso, 2002), and examine how African American students experience and respond to racial microaggressions on a college campus (Solórzano, Ceja, Yosso, 2000).

In qualitative educational scholarship, CRT has also been deployed as an analytic tool in revealing the complicities of race in affirmative action university admission policies (Parker, 2008), analyzing the experiences of African American students at a White private school (DeCuir & Dixson, 2004), and uncovering how it is operationalized in institutions such as an urban middle school (Masko, 2008). Parker (1998) used CRT to analyze the affirmative action policies of an educational legal case. He conducted a study in which he analyzed the underlying assumptions of affirmative action in the legal case *Hopwood v. Texas* through a critical race lens. The court's ruling determined that race should not be used as a determining factor to attain diversity. Using CRT in the analysis, Parker determined that affirmative action was seen as allowing less-qualified applicants admission to a university law school over White Americans rather than viewing it as mechanism for increasing the diversity in admissions.

Masko (2008) also conducted a 2-year ethnographic study in an urban middle school in a midwestern community. Masko (2008) explored the ways in which students and teachers related to each other and constructed meanings both in the classroom and in the school, related to race. Masko found that resistance played a major role in the school at the administrative level, curriculum level, and among students. At the administrative level, administrators protested practices they believed would not be beneficial to the student population. This was seen in the administration's response to job cuts at the school of important staff and also their response to what was deemed as indifference by the district's central office to initiatives made to close the achievement gap among students at the school.

At the curriculum level, resistance was seen in the culturally responsive nature of the curriculum of one teacher. Her resistance was actualized in the types of literature she selected for one of her classes. The teacher also required students to bring articles they felt were more representative of their lives. Furthermore, for an honors curriculum class, which attracted predominantly White students, the teacher made a substantial effort to seek out more students of color who also met requirements for the class. As a result of the teacher's effort, there was a more racially diverse student body in the honors class. Masko also found resistance within students. Students resisted the society's expectations for students of color, who were perceived as low achievers. Some students did this by consciously making an effort to stay in school and persevering rather than selling drugs or dropping out like some of their peers. Some students also resisted multicultural education. One White student resisted the emphasis placed on race and racism in education and at her school, which regularly celebrated events like Black History Month. She believed that "we should be treated the same way," by also emphasizing other groups that have discriminated against. In this sense, the student failed to see the significance of race and how it played out in her ideology.

In mathematics education, some researchers have used CRT to convey counter-narratives of students who succeeded despite dominant narratives of underachievement that prevail in the field. Researchers have used CRT to examine African American students' progress in mathematics over the last 50 years (Snipes & Water, 2005) and to tell the stories of successful African American males in mathematics (Berry, 2005, 2008; Stinson, 2004).

Snipes and Water (2005) conducted case study research in which they interviewed a former state mathematics consultant who described his experience in mathematics education in North Carolina during the 1950s to 1980s. During the participant's tenure as state mathematics consultant, he observed several occurrences of institutional and structural racism. Examples of these included inadequate school resources provided to Black students, tracking students, and low expectations of teachers teaching Black students. The participant also pointed out that before integration, high schools with predominantly Black students required students to take a minimum of Algebra 1 before graduation. After integration, the attitude across high schools in the state was that Black students were not smart enough to take mathematics courses that would prepare them for college. Finally, the study also revealed that after integration, the number of teachers who prioritized nurturing Black students sharply declined. Although Black students were now in schools with better resources, their intelligence was constantly doubted.

Drawing from a larger study he conducted, Berry (2005) tells the stories of two African American male middle school students who experienced success in mathematics. Utilizing CRT for its role in illuminating how race and racism plays a part in shaping schools and schooling practices along with descriptive portraits, Berry investigated the barriers these African American male middle school students encountered and how they overcame these challenges to do well in mathematics. He found that the parents of the students provided early academic experiences to excite and expose their sons to learning in early elementary grades. These early experiences included a number of educational games and activities in the students' early years. Berry also found that the students had experienced substantial discrimination. The students in the study were misdiagnosed with learning disabilities and were wrongly placed in classes that did not challenge them academically. As a way of fighting against these challenges, the parents played the role of advocates for their sons. Berry also found that in addition to strong support systems, the students were self-empowered and highly motivated to be successful in school and mathematics.

Berry (2008) then looked at all eight successful African American males students from his larger study, while telling the story of two of them, along with the barriers they faced in gaining access to high-level mathematics courses. Success was defined as enrollment in Algebra 1 in middle school. Berry's study revealed that the boys embodied alternative identities that enabled their persistence in school and coping with peer pressure. Identities the boys embodied were co-curricular and special academic program identity, religious identity, and athletic identity. In this sense, the boys' participation in extra-curricular activities reified their idea of smartness. Further, seven of the eight boys demonstrated strong spiritual faith and participated regularly in church activities. Finally, five of the eight boys participated in sports throughout the year. Participating in athletics kept the boys focused while they were not in school.

Stinson (2004) conducted a qualitative action research study on the schooling experiences of African American male students who fully participated in school, academics, mathematics, and who were identified as having agency. Agency was defined as the ability of participants to accommodate, resist, or reconfigure the available sociocultural discourses that surrounded African American males in order for them to effectively negotiate these discourses in their pursuit of success. Stinson used a critical postmodern theoretical framework, which drew upon a number of theories, including CRT. He utilized CRT to understand how the discourse of race and racism operated within U.S. social structures. Through the use of CRT, Stinson found that participants identified stereotypical discourses, which suggested that African American females were smarter than Black males. Participants believed that the pervasiveness of this stereotype resulted in lower school and academic expectations of Black male students. Participants suggested that teachers and the African American community embraced lower expectations of Black male students. Participants also challenged widely held negative images of African American males who rejected and were deficient in school.

Common themes among these studies were one of doubt in the abilities of Black students to not only achieve in mathematics, but also to persist in school. The studies in mathematics education were highlighted because they underscore the importance in illuminating the stories of students who, contrary to a dominant discourse of failure, can succeed in mathematics and do well.

Communities of Practice, Identity, Learning, and Mathematics in a Social Context

Educators have questioned traditional methods of teaching and learning mathematics and the ways in which knowledge is transferred to students through those approaches. They have even suggested that types of learning situations define the types of knowledge that students acquire (Boaler, 1999; Boaler & Greeno, 2000). For mathematics specifically, it is the "practices of learning mathematics [that] define the knowledge that is produced" (Boaler & Greeno, 2000, p. 172). In this sense, situations and activities in practice are integral to cognition and learning (Brown, Collins, & Duguid, 1989). Social theories of learning espouse that learning occurs by doing or through practices in social activity (Lave & Wenger, 1991; Wenger, 1998).

In a broader study of identity, scholars have considered various ways in which individuals come to view themselves. Identity-related topics have been explored primarily in the psychological domain (Phinney, 1990; Steele, 1997; Steele & Aronson, 1995). From a psychological perspective, there is also an extensive body of literature that explores how racial identity is developed (Cross, 1991; Fordham, 1996; Hale-Benson, 1994; Helms, 1990; Sellers, Smith, Shelton, Rowley, & Chavous, 1998; Tatum, 1997; Welch & Hodges, 1997). It is, however, beyond the scope of this discussion to consider identity from a psychological perspective. Departing from the view that identity and learning can only be explained by cognitive theories, I support scholars who have taken a more situated perspective (Cobb & Hodge, 2002; Lerman, 2000). Identity in this sense is defined as the negotiation between learners and the social contexts in which they participate in that influence how they view themselves. Some scholars have described the types of identities that emerge from these social contexts. These types of identities include social identities (Askew, 2007; Carr, 2001; Fernie, Davies, Kantor, & McMurray, 1993), learner identities (Weil, 1986), and even a mathematics identity

(Martin, 2000, 2007). Wenger (1998) provides a useful framework for understanding the connection between learning and identity formation that takes place within a social context through communities of practice.

Communities of Practice, Learning, and Identity Formation

Communities of practice defined. A community of practice is a collective group, unified by common interests where members interact regularly in order to create and improve what they learn and share over time. Although various areas of the social sciences use and apply this concept, its origins and utility are found in learning theory. Theories of learning enable an understanding of how learning takes place in humans from a behaviorist, cognitivist, or constructivist perspective, to name a few. Etienne Wenger, a Swiss educational theorist, in collaboration with anthropologist Jean Lave, is noted for first developing the term *communities of practice* (CoPs) (Lave & Wenger, 1991; Wenger, 1998). Some scholars have claimed that both Lave and Wenger (1991) and Wenger (1998) cast a similar, yet "characteristically different [concept] of 'community of practice'" (Kanes & Lerman, 2008, p. 304). For the purposes of this discussion and to provide clarity, I will primarily focus on Wenger's (1998) view of CoPs.

The theory of CoPs espouses that learning requires extensive participation in a community whose members are engaged in a set of relationships over time. Wenger (1998) explains that CoPs exist all around us; they are an important part of our everyday life, and individuals are part of a number of them both implicitly and explicitly. CoPs range from formal to informal; some individuals are core members, and others hold peripheral membership. Clarifying the definition of CoPs, Wenger, McDermott, and Snyder (2002) explain:

> As [members] spend time together, they typically share information, insight, and advice. They help each other solve problems. They discuss their situations, their aspirations, and their needs. They ponder common issues, explore ideas, and act as sounding boards. They may create tools, standards, generic designs, manuals, and other documents—or they may

simply develop a tacit understanding that they share. However they accumulate knowledge, they become informally bound by the value that they find in learning together.…Over time, they develop a unique perspective on their topic as well as a body of common knowledge, practices, and approaches. They also develop personal relationships and established ways of interacting. They may even develop a common sense of identity. (pp. 4-5)

In order to distinguish CoPs from other types of sustained social relationships, Wenger (1998) lists fourteen indicators that a CoP has been formed. They are the following:

1. Sustained mutual relationships – harmonious or conflictual
2. Shared ways of engaging in doing things together
3. The rapid flow of information and propagation of innovation
4. Absence of introductory preamble, as if conversations and interactions were merely the continuation of an ongoing process
5. Very quick setup of a problem to be discussed
6. Substantial overlap in participants' descriptions of who belongs
7. Knowing what others know, what they can do, and how they can contribute to an enterprise
8. Mutually defining identities
9. The ability to assess the appropriateness of actions and products
10. Specific tools, representation and other artifacts
11. Local lore, shared stories, inside jokes, knowing laughter
12. Jargon and shortcuts to communication as well as the ease of producing new ones
13. Certain styles recognized as displaying membership
14. A shared discourse reflecting a certain perspective on the world. (pp. 125-126)

For the purpose of this discussion, I limit my focus to three fundamental but interrelated structural elements that can be used to differentiate CoPs from other closely related social groups.

Structural elements of communities of practice. There are important characteristics that all CoPs embody. CoPs contain a combination of three fundamental elements: a domain of interest or *mutual engagement*, a community or *joint enterprise*, and a focus on practice or *shared repertoire* (Wenger, 1998; Wenger, McDermott, & Snyder, 2002). Without these three critical interrelated elements, CoPs could not exist.

A domain of interest indicates what the group is about. The domain gives the group a legitimate identity, which reifies its purpose and value. This is done by sharing a mission statement or by having common purpose in the group. Domain is connected to mutual engagement. Mutual engagement describes the functionality of a CoP. Through mutual engagement the community is defined. It binds members together into a social entity. The practice of the CoP is not just an abstract or static concept, nor is it just in theory or in one's mind. Mutual engagement represents a practice in which individuals come together to engage in some negotiated set of actions. Furthermore, through mutual engagement in a community of practice each participant "finds a unique place and gains a unique identity, which is both further integrated and further defined in the course of engagement in practice" (Wenger, 1998, p. 76).

The community tells how the group functions. When the community is strong, it fosters interactions and relationships based on a mutual respect. Community is linked to joint enterprise. A joint enterprise is constantly renegotiated; it maintains the CoP and keeps it together. Through joint enterprise CoPs define their collective vision or purpose. As Wenger explains, there are three key features of a community that keep it intact. First, it is the collective process of mutual and complex engagement. Second, it is defined by the pursuit of its participants and belongs to each of them. Finally, its participants, whereby all members are accountable and are an essential part of the CoP, mutually constitute the joint enterprise.

The practice of the group indicates the types of things the group produces. Through practice, the CoPs use specific ideas, tools, and ultimately produce knowledge. Practice is connected to shared repertoire. Shared repertoire represents how CoPs evolve over time and the capabilities they produce. Through the joint pursuit of an enterprise, resources are used in specific ways that become important in negotiating new meaning. The shared repertoire of CoPs includes the common language, routines, and ways of doing things that its participants engage in. Moreover, through a shared repertoire, the participants are able to articulate their forms of membership and their identities as members.

There are also other important structural elements that CoPs possess. CoPs are diverse and take on a variety of forms. CoPs can range from small to big, long-lived to short-lived, collocated to distributed, homogeneous to heterogeneous, inside to across boundaries, spontaneous to intentional, and unrecognized to institutionalized (Wenger, McDermott, & Snyder, 2002). These distinctions are useful so that CoPs can be easily recognized.

CoPs range in size. Some can be quite large, and others are small. Some CoPs have few members, with very specialized expertise, and others have large groups located in various geographic regions where all members are encouraged to participate. CoPs can also exist over long periods of time. Mathematics educators, for example, have a history of practice that span several decades. Then there are CoPs that have only existed for just a few years. Because CoPs require regular interaction, some of them operate among individuals who live within close proximity, whereas others are across many cities. Communication in these CoPs can be transmitted through emails, websites, phone, and face-to-face contact. The key here is that, no matter where the CoPs are located, there is a shared practice. No matter where the CoPs exist, there is a common understanding, a common set of issues that the community deals with, and a common way of looking at problems. CoPs can also be composed of individuals with similar backgrounds, whereas others have individuals that are more diverse. If the backgrounds of the individuals in the CoP are not similar, then members are unified through a common issue or concern. This unification helps to build the community’s shared practice. CoPs can emerge naturally and informally from repeated conversations in the group. They can also be intentionally created for a specific purpose. Some CoPs come together spontaneously because of a specific need that must be addressed. Other CoPs are very structured in their formation and conduct themselves with rather specific protocols, like agendas, meeting schedules, or meeting minutes. Finally, some CoPs can go unrecognized, whereas others can be institutionalized. Because some CoPs happen naturally, there may not be public acknowledgement of their existence. Despite this lack of awareness, some CoPs that go unrecognized develop shared knowledge that can inform the practice of a community at a later time. CoPs that are formally established are used in some organizations because their presence serves a specific need of a broader community.

Modes of belonging in identity formation. An integral component of any community of practice and an important part of learning is construction of identities. Participants in a community build their image of how they see themselves through the positions they hold, which greatly influences their construction of identity. In regards to identity formation and learning, Wenger offers three distinct modes of belonging: engagement, imagination, and alignment.

Similar to mutual engagement, engagement describes interactions as an ongoing collaboration with members in communities that can change. Engagement involves three processes: ongoing negotiation of meaning, the formation of trajectories, and the unfolding of histories of practice (Wenger, 1998, p. 174). The simultaneous interaction of these three processes allows engagement to become a form of belonging, which is how identity unfolds. More important, through engagement in a community a shared reality is created and aids in constructing identity. Engagement embodies natural boundaries because of limitations of time to participate in the community, activities one can become involved in, and relationships that members of the community develop with one another. Because of these limitations, engagement often has both strengths and weaknesses.

In a community, imagination is the ability of members to create new images of themselves beyond time and space. Imagination is a creative mental process that can be thought of as the ability to dream about what is possible for oneself and what one is capable of becoming. Unlike engagement, which is concretized in creating a shared reality, imagination supersedes direct interaction and is another form of constructing a shared reality. Our imaginations allow us to locate ourselves in the social world, past, present, and future. In this mode of belonging, the scope of our reality is expanded along with our identity.

Alignment is the mode of belonging in which all efforts, such as energies, actions, and practices, come together to produce coordinated activities. Alignment allows participants in a community to play their unique roles in finding common ground. Participants are able to arrange their practices within the guidelines and expectations of the community to maintain alignment. Finally, alignment necessitates very precise forms of participation and structure.

Each of the three modes of belonging has its share of shortcomings. One mode should not be thought of as better than another. Each should be thought of as working cohesively with the others in the construction of identity. To better understand the processes of identity formation, consider Figure 2.1. It shows the interconnection of the three modes of belonging, and the possible elements of each that are negotiated.

Identification and negotiability in identity formation. In addition to the modes of belonging, Wenger (1998) also clarifies that identity formation is an interconnected process of identification and negotiability. Through this duality, "our identities form in this kind of tension between our investment in various forms of belonging and our ability to negotiate the meanings that matter in those contexts" (p. 188). In other words, there is mediation between one's ability to identify or belong and one's understanding of the degrees of what it means to belong in various

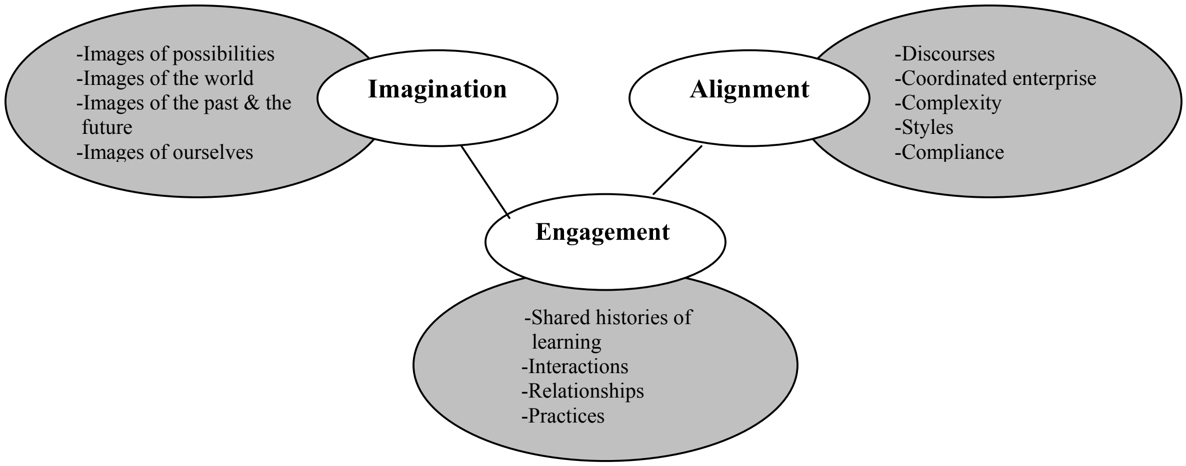


Figure 2.1. Modes of belonging in identity formation. (from Wenger, 1998, p. 174).

contexts.

Wenger (1998) defines identification as the "process through which modes of belonging become constitutive of our identities by creating bonds or distinctions in which we become invested" (p. 188). In other words, identification can be thought of as the process of becoming a member of the CoP, possessing a personal and deep level of allegiance to the CoP, and engaging in activities that signal membership in that community. Identification itself is dynamic and complex, a generative process that changes. Identification should not be thought of as just how individuals relate to one another. It is also the interplay of all aspects of what makes CoPs possible; from the participants to the enterprises that participants are a part of.

Negotiability is defined as "the ability, facility, and legitimacy to contribute to, take responsibility for, and shape the meanings that matter within a social configuration" (Wenger, 1998, p. 197). In other words, negotiability is a process of understanding what sense is made of the meaning in the things we place upon ourselves and that are placed on us. Wenger also suggests that negotiability is "shaped by relations of ownership of meaning" (p. 200), which enables meanings to embody various degrees of value. Identification and negotiability interact with the modes of belonging to aid in the understanding of identity construction.

Trajectories and learning in CoPs. In CoPs, identity is produced from the very act of participation and the meaning that is created for oneself within that participation. This work is far from static – it is ongoing. One might even say that it is a “constant becoming” (Wenger, 1998, p. 154) and in some respects something that we reexamine throughout the course of our lives. Wenger suggests that as we go through various forms of participation, our identities formulate trajectories inside and throughout the CoPs. Wenger’s (1998) notion of a trajectory should not be characterized as a charted or predetermined path. It should however, be considered as “a continuous motion – one that has momentum of its own” (p. 154). In CoPs, as members move from peripheral participation to full membership, they might find themselves on various trajectories such as peripheral trajectories, inbound trajectories, insider trajectories, boundary trajectories, or outbound trajectories.

Peripheral trajectories seldom lead to full participation by members in the CoPs. This decision may be voluntary or required, but it still gives individuals access to the community whereby some aspect of their practice can influence their identity. An inbound trajectory suggest that individuals seeking membership in CoPs become part of the community with the intention of becoming full participants over time. The identities that individuals formulate are interconnected with the participation they hope to have in the future, even though their position as newcomers may only afford them marginal participation at the time. An insider trajectory allows individuals to go beyond full membership. Their practice allows new innovation and constant reexamining of their identities for something new and different. Boundary trajectories enable connections to be made between other CoPs along with the identities that must be sustained in these spaces.

Finally, an outbound trajectory in some sense prepares individuals for their role in the community as they decide to transition from the community. Identities are then contingent on how they view themselves and the world as they make these transitions.

The relationship of identity and learning are important here because as we reexamine the identities we create for ourselves, it defines how we engage in our practice. In this sense, engagement is not fixed, but can shift as our identity shifts. As a consequence, what is prioritized in our learning is contingent upon what trajectory we find ourselves on. Wenger (1998) points out that "a sense of trajectory gives us ways of sorting out what matters and what does not, what contributes to our identity and what remains marginal" (p. 155).

Wenger's framework provides a way of considering the practice of doing mathematics in an out-of-school context. Wenger's explanation of CoP, modes of belonging, and identification and negotiability, and trajectories were important in framing this study because they provided a lens for understanding what to look for in determining what identities were constructed in workshop training with CMLWs and MLWs at a particular training hub. It also enabled me to understand what kinds of negotiation took place in the Flagway number categorizations. In the next section, I discuss how CoPs have been used in research.

Research on Communities of Practice and Mathematics in a Social Context

Communities of practice are an emergent topic in the research literature; however there are very different accounts by scholars of what CoPs actually mean. Not all scholars refer to Wenger's (1998) work or even to Lave and Wenger (1991) in their conceptualization of CoPs. The majority of the studies that I highlight here draw from Wenger's (1998) notion of CoPs. Because the body of mathematics education research on CoPs is growing, I do cite some studies that draw from Lave and Wenger (1991) since the two perspectives are related.

CoPs in research. From their inception, CoPs have been used primarily to study how commercial organizational systems function. In an effort to further understand and extend the CoP framework in this area, researchers have worked to broaden its definition (Manville & Foote, 1996; Orr, 1990; Seely Brown & Duguid, 1996; Stewart, 1996) and to investigate how it might be applied across international boundaries (Hildreth, Kimble, & Wright, 2000). Beyond commercial systems, researchers have made efforts to expand their understanding of CoPs in other domains such as education and the other social sciences.

In the social sciences, CoPs have been used to further studies in sociolinguistics, with special attention given to research on language and gender (Bergvall, 1999; Bucholtz, 1999; Eckert & McConnell-Ginet, 1999; Ehrlich, 1999; Freed, 1999; Holmes & Meyerhoff, 1999; Meyerhoff, 1999). Research on CoPs in educational organizations has been conducted to better understand the practices that influence daily life in workgroups of deaf academics in a university setting (Trowler & Turner, 2002). Educational anthropologists who study teaching and learning both inside and outside schools have looked at understanding the knowledge that is brought to a CoP of novice child-care teachers (Bradley, 2004). In medical education, CoPs have been used as a framework for analysis in clinical teaching and learning for students training to be health professionals (Egan & Jaye, 2009). In the virtual domain, scholars have used the framework to ask whether online CoPs constitute a community of learners (Reimann, 2008). In teacher education, CoPs have been used extensively to understand how teachers come to learn and practice in social contexts. CoPs have been used to understand how to prepare and support literacy educators in a single diverse community (Au, 2002), to advance an educational reform agenda (Lieberman & Pointer Mace, 2008), and to document the changing roles of teachers utilizing technology in classrooms (Hartnell-Young, 2006). CoPs have been used as a strategy for effective professional development in the training of teachers to connect and interact with each other (Looi, Lim, & Chen, 2008). Professional developer training teachers have used CoPs to explore a nontraditional professional development process, which involved a small group of teachers and a professional developer working as a collaborative community (Fougler, 2005).

CoPs in Mathematics Education Research

There has been a growing effort to extend Wenger's work on CoPs in mathematics education. In mathematics education, CoPs have been used to describe and clarify teacher learning (Adler, 2001; Graven, 2002, 2004; Stein & Brown, 1997) and student learning (Boaler, 2000; Santos & Matos, 1998). Further, CoPs have been used to look at how mathematics learning communities are developed in primary classrooms (Price, 2003) and to study identity and how it plays its role in learning in the mathematics classroom (Cobb & Hodge, 2002).

Research on teacher learning. Adler (2001) interrogated the teaching dilemmas that 6 teachers in multilingual secondary level mathematics classrooms negotiate within a post-apartheid South Africa. Because of multilingual backgrounds that both teachers and learners bring to mathematics classroom in South Africa, Adler was particularly concerned with how the mathematics teachers mediated their practices in these communities. Although the study was grounded in ethnographic methodology, Adler used social practice (Lave & Wenger, 1991) and socio-cultural theoretical perspectives to understand emerging issues around teaching and learning that arose in these multilingual classrooms. In Adler's findings, she describes these dilemmas as code-switching, mediation, and transparency and argues that teaching dilemmas in general are situated and have contextual meaning. Adler found that teachers expressed a variety of issues related to the three dilemmas. For instance, because the official language is English in South Africa and for learners whose main language was not English, many teachers expressed occasional difficulty explaining mathematics. Further, learners had difficulty articulating what they understood in mathematics in English. Adler also found that because of the changing discourse of codeswitching in these communities, mathematical meaning of very explicit mathematics terms like *not more than* and *at least* were negotiated between everyday and mathematical language, and between verbal and symbolic forms. Adler also found that teachers had to negotiate the explicit mathematics language of the classroom. In this sense, language became the focal point in the mathematics classroom, as opposed to the mathematics that was trying to be taught. Through this negotiation, the mathematics often became lost.

Graven (2002) conducted a longitudinal study in South Africa in which she looked at what mathematics teachers learn through participation in a community of practice stimulated by a new curriculum change effort. One important finding of the study was that through the CoP, teachers identified new roles for themselves and saw their learning as another way of connecting to their practice. For example, before membership in the mathematics community, one teacher identified herself as a music teacher and after membership, identified herself as a "maths teacher." Graven (2002) also found that through membership in the mathematics community teachers' identity grew stronger.

Drawing from the same longitudinal study, Graven (2004) looked at the primary role of confidence in understanding the learning of teachers that occurred within a mathematics in-service program prompted by curriculum change. Although not a focus in Wenger's work, it was Graven's goal to bring confidence to the fore to extend Wenger's framework. Graven argues that confidence too is a necessary component of learning, just like meaning, practice, identity, and community. In the study, she found that confidence was both a product and process in the mastery of becoming and being a professional mathematics teacher. That is, confidence was necessary for the teachers to move from being teachers of mathematics to becoming competent and confident mathematics teachers. Graven also recommends extending the literature on confidence to a social perspective, because confidence is primarily seen within a psychological domain.

Research on student learning. Drawing from Lave and Wenger's (1991) work, Price (2003) studied how a learning community in the classroom could be established between a teacher and 27 primary school children learning addition. The study took place in England with students 4 to 9 years old. Price found that both teacher and the students created an environment in the classroom where making mistakes and just trying to do the mathematics was accepted. Price found no incidents where the teacher explicitly told students that they were doing the mathematics wrong. When wrong answers did surface, the teacher asked the class whether they agreed with the student giving the answer. She then encouraged the student to rethink their response by telling them that their answer was "nearly" correct. Students were also encouraged to use mathematical discourse during lessons. Price also found that because of the establishment of the community, the result was a positive effect on the students' motivation to do mathematics and how they viewed mathematics overall. Further, Price also found that the students wanted to gain mastery in mathematics and to become more able learners.

Cobb and Hodge (2002) presented a discussion on a relational perspective of cultural diversity and equity using CoPs as a possible analytic tool to foreground local communities outside of school, such as home communities. Further, as another possible analytic tool, notions of discourse (Gee, 1997), which is the daily language produced by various types of communities, were also suggested since it can distinguish between broader communities within society. Cobb and Hodge drew from these two perspectives and suggested that taken together, they might be a fruitful way of analyzing the "classroom microculture [if] the teacher and students in a classroom necessarily constitute a community" (p. 273). Cobb and Hodge also suggest that CoPs and discourse might be useful in analyzing mathematical practices in the classroom because of the cultural capital that is negotiated between members.

Identity and mathematics in socio-cultural practice. There is a common belief that the primary context where students acquire the mathematics they learn is in schools. Challenging this notion, researchers have studied learning as participation in daily cultural practices and out-of-school contexts to better understand how adults and students acquire basic mathematical concepts. In earlier studies, researchers examined mathematics in everyday situations, like the use of arithmetic (de la Rocha, 1985; Murtaugh, 1985; Scribner, 1984), geometry (Millroy, 1992), rational number concepts (Carraher, 1986), and measurement (Masingila, 1994). Researchers have considered mathematics learning in out-of-school activities like candy selling (Saxe, 1988a; 1988b), carpet laying (Masingila, 1994), playing educational games (Saxe & Guberman, 1998), and playing basketball and dominoes (Nasir, 2002). Common themes of research in this area suggest the following as it relates to learning in out-of-school situations: (a) the mathematical knowledge that individuals bring to out-of-school activities are more than adequate; (b) mathematical procedures are created on the spot as needed; (c) mathematical activities are structured in relation to the ongoing activity one engages in; and (d) identities are always in constitution as individuals engage in practice.

Carraher (1986) conducted a comparative study between students and construction foremen in Brazil to examine their knowledge of scales, which is based on proportional reasoning. The students selected for this study were seventh graders attending a middle school that served middle-class to affluent families. The construction foremen selected for the study acquired informal knowledge about their profession either by some apprenticeship training or through friends. Four types of scales were presented: two that were commonly used in construction, and two that were not. Carraher found that the students had very strong syntactic abilities in solving scale problems, but had a rather difficult time making meaning of the work they carried out. Furthermore, a majority of the students in the study created their own methods for solving problems. The construction foremen, on the other hand, had no problems in understanding the meaning of the problems and were able to work more efficiently even when utilizing the same problem-solving strategies as the students used. They used hypothesis testing, and those who used it were very familiar with the scales with which they worked. Because of these differences in meaning, Carraher suggests that students learning more about proportions should engage in deeper reflection so that they will have a more rounded understanding of the concept.

Saxe (1988a, 1988b) conducted a study to investigate how daily activities performed by children enabled their numerical understanding. In his work with child street vendors in Brazil, Saxe investigated the mathematical goals they developed in their day-to-day practice of handling currency. As a method for understanding these goals, Saxe (1988a) investigated the sellers' practice- linked understandings of representing large numerical values, arithmetical manipulation of numerical values, comparison of ratios, and adjustment for inflation in wholesale to retail markups. Saxe (1988b) also looked for selling strategies and solutions among sellers and two groups of nonsellers (urban and rural). In support of the themes mentioned earlier, findings from this study suggested that sellers acquired mathematical knowledge needed to engage in practice-linked tasks. Saxe also found that despite the limited availability of schooling in Brazil, sellers and both groups of nonsellers were able to organize their currency system to represent large numerical values in adequate ways. This study showed the limited connection between the school-based mathematics and the out-of-school mathematical activities of sellers. The study also supported the rationale for a stronger connection between the mathematics that is learned in schools and in out-of-school activities.

In a later study, Saxe and Guberman (1998) examined the mathematical goals that elementary school age children formulated as they engaged in joint play of an educational mathematics game they created called Treasure Hunt. Saxe and Guberman compared dyads of different ability groups in game play to understand the types of goals children set up when solving mathematical problems. They found two principal forms of social interaction that took place during game play by students: direct assistance and thematically organized assistance. In game play, students directly assisted their opponent in varying degrees to solve problems. Students also achieved thematic goals during game play when solving joint problems. In that way, students relied on prior mathematical knowledge and invented character roles during game play to accomplish certain tasks. Because the game primarily dealt with purchase transactions, children assumed specific roles as shopkeepers and customers to accomplish mathematical tasks. Saxe and Guberman chose three samples to conduct their study: two ability groups, similar and mixed, and one control group. Their primary interest was in the mathematical aspect of the children's work during game play. Identity themes emerged in their findings but were not explicitly addressed through the roles that students invented. The themes were seen in the goals students created to solve problems by *becoming* or *adopting* character roles to complete tasks during game play.

Aligning with earlier themes described and using Wenger's (1998) framework to explicate modes of belonging in identity formation, Nasir (2002) describes findings from two studies she conducted on mathematics learning, both focused on African American students engaging in out-of-school cultural practices of dominoes and basketball. Nasir's research also builds on Saxe's work, considering the practice-linked goals, mathematical goals, and identity that students have in their practice. Nasir examined the relationship between culture, practice-linked goals, and identity formation of students in these two contexts. In both basketball and dominoes, the findings suggested that players required a competency in mathematical operations, probability and logic, and statistics to make calculated moves in each game. More important, the mathematical goals of the students playing both games depended on their age and level of engagement in each game. The identity of students playing dominoes shifted because of the changing nature of their engagement. This shift in identity was related to the new ways each group participated in the practice of dominoes. The students in elementary school and high school, made different investments in how they played dominoes. The high school players had a more rapid playing style and paid more attention to the game than the elementary school players. The high school students moved between game and nongame talk while playing dominoes. Using the playing skills they developed, the players also developed respect, and in some cases disrespect, for their partners and opponents over time. The elementary school player's relationship with one another was connected to how they saw each other outside of the game. Students with "large amount of power and authority outside the game context" (p. 229) were deferred to consistently. Furthermore, because the elementary school students were new to the game of dominoes, there was little shared experience with the game.

For students playing basketball, all modes of belonging, engagement, alignment, and imagination changed, which also reflected changes in players' practices. For engagement, students playing basketball were committed to playing the game. They practiced diligently, were dedicated to winning, and maintained professionalism. For alignment, players referred to themselves as “ballers” and kept current with professional players by reading magazines, watching games on television, and keeping track of their score statistics and major trades. For imagination, high school players connected themselves to those in their community that were afforded the opportunity to play basketball in college. All of these students, with the exception of one, saw themselves playing basketball in college.

These studies were considered because they focused on out-of-school contexts where mathematics is learned. These contexts were related to my study. Although identity was not a focal point in all of these studies, some studies did reveal that adapting identities could be a consequence of engagement in social practice. Further, the present study built upon Nasir’s work, where she investigated the identities adopted as a consequence of students’ engagement in an out-of-school context where mathematics learning took place.

Research on Functions and Prime Decomposition

Student Understanding of Functions

Functions can be seen in various places across mathematics from elementary concepts to more advanced topics (Lloyd & Wilson, 1998; Szydlik, 2000; Williams, 2001). There is a consensus among researchers that the concept of function is essential to teach and that students must learn it in order to deepen their understanding of mathematics (Dubinsky, 1993; Kalchman & Koedinger, 2005; Knuth, 2000; Lacampagne, Blair, & Kaput, 1995; Leinhardt, Zaslavsky, & Stein, 1990). While the research literature on functions is quite vast, my aim was to organize this review according to what the research has informed us on students’ understanding of functions and the types of functions that have been studied.

Because of its complexity, many students have difficulty in understanding function. Leinhardt, Zaslavsky, and Stein (1990) cite three reasons why functions are difficult for students to master. They suggest that the concept of function is often connected to other mathematical concepts; it draws from various fields of mathematics; and functions can have multiple representations (Dreyfus & Eisenberg, 1982). Kalchman and Koedinger (2005) also cite reason why they believe students to do not understand functions. They suggest that when “students’ conceptual understanding and metacognitive monitoring are weak, their efforts to solve even fairly simple algebra problems can, and often do, fail” (p. 353). Sajka (2003) offers other reasons for students’ difficulty in understanding. Functions have an inherent abstractness in their notation, and there are restrictions in symbol representation when teaching and limitations in the mathematical tasks are offered at schools.

Researchers have proposed that students have varied understandings of the definition of function. Although they may be able to explicitly give a definition of a function, students have a rather difficult time applying that definition to graphs (Vinner, 1983). Misunderstandings are also seen in graphical representations when students are asked to classify functions in various tasks (Vinner, 1983; Vinner & Dreyfus, 1989). This research also suggests that students have limited ideas of what graphs of functions can represent. Often, students fail to recognize graphs of functions that are unusual or that they have not come across before.

Researchers have also reported that students have a difficult time understanding correspondence (Lovell, 1971). Students seldom understand correspondences that are different from one-to-one. Many students only consider examples of functions with the one-to-one property. They are often confused by the concept of many-to-one and one-to-many correspondences. Researchers have suggested that this confusion may stem from a lack of examples provided to students of many-to-one correspondence cases (Markovits, Eylon, & Bruckheimer, 1986; Thomas, 1975; Vinner, 1983).

Several studies have also suggested that students gravitate towards linearity situations when demonstrating their understanding of functions in tasks. For students' prototypical concept images, Schwarz and Hershkowitz (1999) found that students often used linear functions although they do report that some students occasionally used quadratic functions. Lovell (1971) also reported that when asked to define a function as a relation, many students provided examples that were linear. Markovits, Eylon, and Bruckheimer (1986) found that when students were asked to create functions that passed through two given points, most of the examples they provided were of linear graphs. Elsewhere, scholars have reported similar results (Dreyfus & Eisenberg, 1983; Zaslavsky, 1987) for other tasks.

Research on Prime Decomposition

The decomposition of natural numbers is as an elementary number theory concept. Although important, elementary number theory concepts have not received significant attention in mathematics education research. Studies in this area have focused primarily on the domain of teachers' content knowledge for teaching mathematics. Past studies have examined multiplicative structures applied in specific contextual situations such as word problems that use division and multiplication (Ball, 1990; Graeber, Tirosh, and Glover, 1989; Vergnaud, 1988). There have also been studies that looked at pre-service teachers' understanding of divisibility and multiplicative structures of natural numbers. Such structures include the conceptual properties when decomposing natural numbers into unique products of prime factors (Zazkis & Campbell, 1996a; 1996b). Zazkis and Campbell's (1996b) work with pre-service teachers' conceptual understanding of prime decomposition is of specific interest, because their findings underscore the difficulty of grasping factorization and decomposition as a concept.

Zazkis and Campbell (1996b) conducted a study with pre-service elementary school teachers taking a foundations of mathematics course. The participants were introduced to elementary number theory concepts, which included the Fundamental Theorem of Arithmetic. The Fundamental Theorem of Arithmetic says that every natural number greater than 1 can be decomposed into a unique product of prime factorizations, except for the order of the prime factors. The participants were given three assessment questions and asked to answer each one by providing an explanation. This study foregrounds participants' procedural and conceptual understanding of prime decomposition, and another study by Zazkis and Campbell's (1996a) explored the participants' understanding of divisibility. In the study of prime decomposition, Zazkis and Campbell (1996b) found that although the pre-service teachers were able to recite the Fundamental Theorem of Arithmetic, their understanding of it was limited. Zazkis and Campbell suggest that pre-service teachers' difficulty in decomposing composite numbers into prime factors may come from their previous experiences expressing composite numbers as products. That is, if concepts of prime and composite numbers are not well constructed, that may prevent a meaningful conceptualization of prime decomposition.

I reviewed research on functions and decomposition because the Flagway Game is related to these two concepts. I considered including research on the Möbius Function for this review because it is also connected to the Flagway Game. Although there is much mathematics research on the Möbius Function, I did not find any studies of Möbius Function in mathematics education.

CHAPTER 3

METHODOLOGY

> I've been through the conventional way of education. I'm thankful to it for getting me to where I need to be. But I really find that there were a great deal of flaws with my education, the way it was given to me. And it had an effect on me and my level of performance once I reached higher levels of academia. And so I, at this point, I'm willing to undergo or figure out any new way of instituting certain forms of education that will make these things more exciting [to students], to build their confidence, and to have them more willing to take anything on that comes in their path. (DeMarcus, College Mathematics Literacy Worker, 2007)

The main purpose of this study was to understand what mathematics literacy identities college mathematics literacy workers (CMLWs) and high school mathematics literacy workers (MLWs) of the Young People's Project (YPP) Chicago had as participants in the Flagway Game Workshop training. Detailed descriptions of YPP and YPP Chicago are given in chapter 1. Also, how did implementing the Flagway Game, influence these participants' understanding of the mathematics they used? In the next section, participant descriptions and the research context for this study are provided.

Participant Descriptions

The participants for this study were four mathematics literacy workers, two CMLWs, Naomi and DeMarcus; and two MLWs, Charlene and Phil (pseudonyms selected by me and approved by each participant). I informed each participant in advance about the purpose of the study and what their involvement would require. They were informed that the focus of the study was the mathematical experiences of CMLWs and MLWs and how those experiences influenced their mathematics literacy identities and their understanding of mathematics used in the Flagway Game. At the time of the study, the two CMLWs were undergraduates enrolled at the same university, and the two MLWs were enrolled at the same high school.

Naomi

Naomi was a college mathematics literacy worker. She was a 21-year-old African American senior at New University. She had been born and raised in the South, but attended college in Chicago. Naomi was a triple major in African American studies, gender studies, and performance studies. She had worked with nonprofit organizations since she was 14 and became familiar with YPP through other youth-oriented work she was involved in. Naomi enjoyed working with young people of all ages. At the time of the study, she had been involved with YPP for about 8 months, which included summer and fall semester work in the organization. Naomi returned to Abelin High for a second semester in January 2007 to give workshops.

DeMarcus

DeMarcus was a 21-year-old African American college mathematics literacy worker. He was a fifth year senior at New University. Native to the South, he attended college in Chicago. At New University, DeMarcus was majoring in African American studies with a concentration in history. During the previous 2 years, he realized that teaching was the career he wanted to pursue, and his work with YPP enabled him to improve his teaching skills with young people. At the time of the study, DeMarcus had been in YPP since the fall semester and returned to Abelin High for a second semester in January 2007 to give workshops.

Charlene

Charlene was a high school mathematics literacy worker. She was a 15-year-old African American sophomore at Abelin College Preparatory High School. A native of Chicago, Charlene lived within walking distance of Abelin. She was returning to YPP after the fall semester. Charlene loved school and identified mathematics as her favorite subject. She enjoyed working with young people, exposing them to different approaches to doing mathematics.

Phil

Phil was a high school mathematics literacy worker. He was a 15-year-old African American sophomore at Abelin College Preparatory High School. He was a native of Chicago and lived within walking distance of Abelin. Phil was returning to YPP after the fall semester. He considered himself an outgoing person and liked to speak up in class. His favorite subject in school was journalism. Phil enjoyed working with young people and believed that his work in YPP helped kids have a future in mathematics.

Context

The Flagway Game

The Flagway Game is a number theory game derived from the Möbius Function. Developed by August Ferdinand Möbius and first introduced in 1931, the Möbius Function is a multiplicative function from number theory and combinatorics. It is defined as follows:

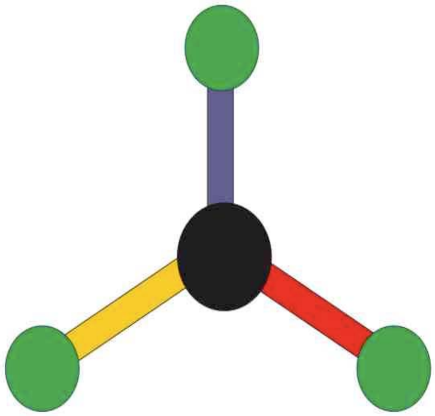
$$\mu(n) \equiv \begin{cases} 0 & \text{if } n \text{ has one or more repeated prime factors} \\ 1 & \text{if } n = 1 \\ (-1)^k & \text{if } n \text{ is a product of } k \text{ distinct primes,} \end{cases}$$

where $\mu(n)$ is defined for all strictly positive natural numbers n and has its values in {-1, 0,1} depending on the factorization of n into prime factors.

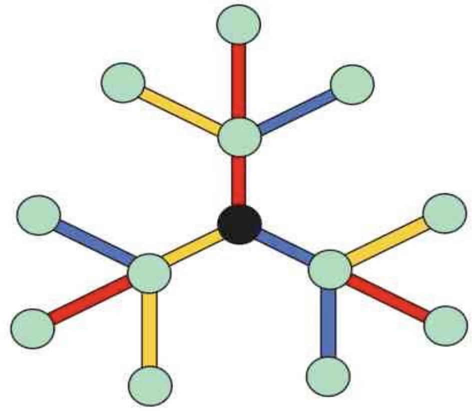
The Flagway Game was developed to help young people expand their understanding of natural numbers. In addition to the competitive part of Flagway, there is also an instructional component. In an experiential approach to learning, students use additive and multiplicative reasoning to recognize and explore patterns of the natural numbers from, 2 to 100 (O. Moses, 2006). Much like the Möbius Function, the premise of the Flagway Game is that each natural number can be written as a product of prime factors and classified into one of three discrete categories: (a) a product of an odd number of distinct prime factors that are not raised to any power, (b) a product of an even number of distinct prime factors that are not raised to any power, and (c) a product of prime factors some of which may be raised to a power. In the Flagway Game, each of these categories is assigned a designated color: red, blue, and yellow, respectively. It is important to note that unlike the Möbius Function, where the number 1 is included in one of the three prime factorization categories, in the Flagway Game the number 1 is not included in the color categorization. The rationale is that 1 is not a prime number.

Levels of the flagway structure. There are three levels of a Flagway structure that students learn before playing the Flagway Game. Each level builds on the previous level. A Level 1 Flagway structure is a tree diagram with three paths that are red, blue, and yellow. The colors represent the three discrete categories explained earlier. When students are first introduced to Flagway, they practice on a Level 1 structure, which helps them learn how to decode natural numbers and put them in one of the color categories. At the end of each color path on the Level 1 Flagway structure, three additional paths of red, blue, and yellow can be drawn, for a total of nine new paths on the tree diagram. This creates a Level 2 Flagway structure. At the end of each of the nine color paths on the Level 2 structure, three additional paths of red, blue, and yellow can be generated again, for a total of 27 paths. This is called a Level 3 Flagway structure. The Flagway Game in typically played on a Level 3 structure. Figure 3.1 illustrates the three levels of the Flagway structure.

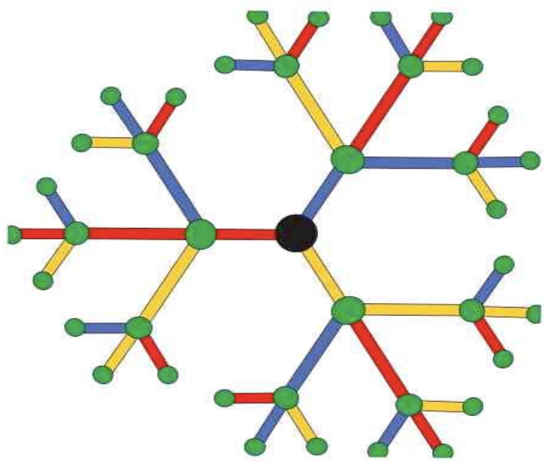
Playing the flagway game. In a recreational facility, like a gymnasium, players of the Flagway Game are divided into three teams and form three lines facing a large floor-sized model of a Level 3 Flagway structure. In front of each line, a basket full of colored pieces of paper is placed on the ground. The color pieces of paper are called *flags*, and each contains a combination of three natural numbers greater than 1. Each team has at least five players and



Level 1



Level 2



Level 3

Figure 3.1. Levels 1, 2, and 3 of the Flagway structure.

is provided with their very own colored flags for team identification purposes. Each team has either red, yellow, or blue colored flags. At the sound of a buzzer, one player from each team grabs a flag from the team's basket and races to the starting point of the Level 3 Flagway structure. They take turn physically navigating the course of paths, to get their team's flag into one of its 27 goals. This is repeated for a specified period of time until a buzzer sounds again for everyone playing to stop. At the end of the game, monitors designated to each team check by counting how many flags for each team were placed correctly into the 27 goals. The team with the most correct flags all together in the 27 goals wins. Figure 3.2 illustrates one player at the starting point of the Level 3 Flagway structure on the game board, and physically navigating his or her blue flag (i.e., 2, 4, and 6) to its goal. He or she first moves from the starting point to the red path on Level 1 because the 2 is assigned red; then to the yellow path on Level 2 because the 4 is assigned yellow; then to the blue path on Level 3 because the 6 is assigned blue; and finally placing the blue flag in the goal.

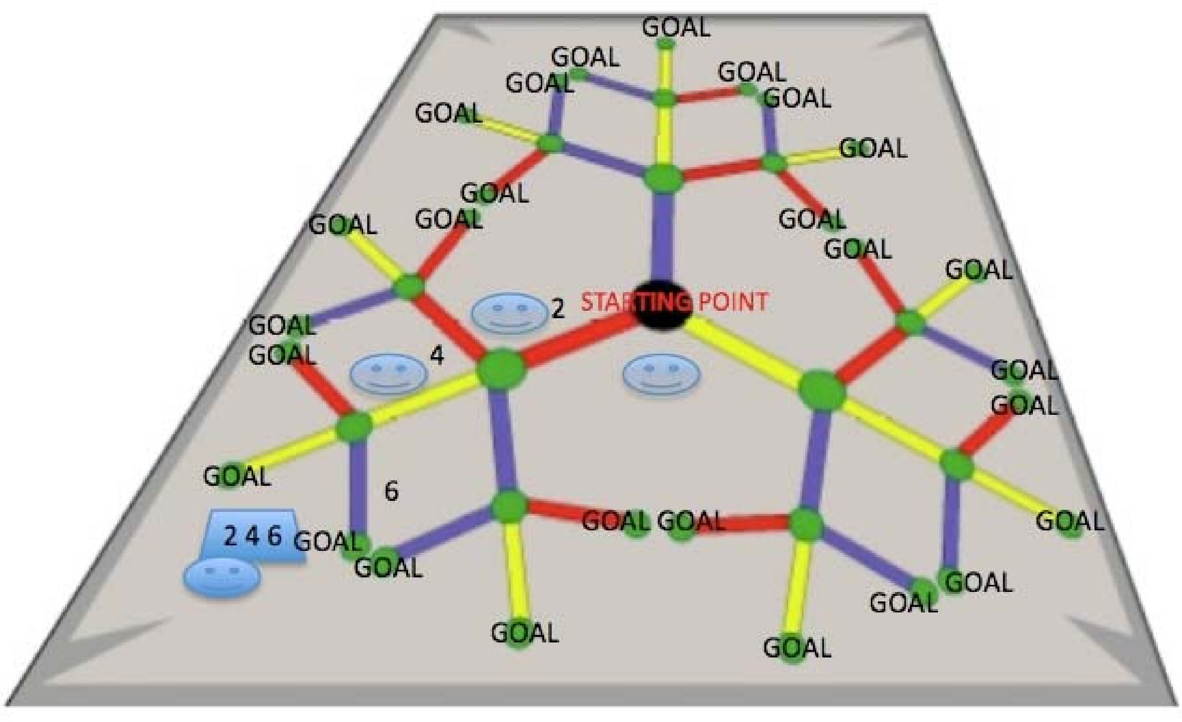


Figure 3.2. Illustration of one player's moves on a level 3 Flagway game board

Many of the fundamental ideas of Flagway are explored using algebraic reasoning. One important feature of CMLWs' and MLWs' developing a deep understanding of natural numbers and playing the Flagway Game is that they are *not provided* the definitions of the three categories previously described. By engaging in a series of mathematical activities in Flagway workshop training together, CMLWs and MLWs discover these categories on their own. Through workshop training sessions reflection, the CMLWs and MLWs develop their own theories about the categorizations and then put them to the test as they use more numbers. As they are exposed to more numbers, there may be some revision to the theories they develop of where the numbers should go. The premise used for playing and teaching the Flagway Game in this way is that if students learn to think critically about their early choices using some algebraic concepts, they will begin to build algebraic reasoning, learn new facts about numbers, learn other important mathematics literacy skills, and, more important, begin to build confidence in themselves on how they explore mathematics.

Train-the-Trainer Model

The train-the-trainer model was originally developed by the Hay Group in Boston. Jim Burruss, a Hay Group consultant, initially worked with Jeff Howard on the Efficacy Project. Robert Moses was part of the Train the Trainer sessions for the Efficacy Project and later developed the train the trainer model for the Algebra Project. Jim Burruss and Bill Crombie, an Algebra Project consultant, developed a similar program for Algebra Project's professional developers, which is called Professional Development for Professional Developers.

YPP used a train-the-trainer model, in preparing mathematics literacy workers to implement the Flagway Game in training sessions and in elementary schools. For example, YPP instructors, who were former CMLWs, trained and facilitated CMLW Flagway Game training sessions. Once the CMLW Flagway Game training sessions were completed, the YPP instructors together with the CMLWs went to specific training hubs and trained MLWs. After 4 weeks of workshop training in this setting, the CMLWs and MLWs went to designated elementary schools, where they taught students how to play the Flagway Game and worked with them 2 days a week until the end of the semester for approximately 12 weeks.

After the CMLWs and MLWs taught elementary students the Flagway Game, they prepared them for a Flagway Game tournament. The tournament was a one-day event held at the end of the school year in which CMLWs, MLWs, and elementary school students competed in playing the Flagway Game. The event culminated the work done throughout the semester and provided a way for everyone who participated to engage in mathematics through entertainment and competition. Figure 3.3 depicts the train-the-trainer model that represented the training in each setting and the duration of the Flagway Game implementation at elementary schools. The CMLW Flagway Game training lasted 2 weeks; the MLW Flagway Game training lasted 4 weeks and; the implementation of the Flagway Game in elementary schools lasted 12 weeks. I participated in two training settings, the CMLW and MLW Flagway Game training. I collected my data for the study during the MLW Flagway Game Workshop training. In the next section I provide a description of how CMLW Flagway Game Workshop training was conducted. I then describe how MLW Flagway Game Workshop training was conducted.

CMLW Flagway Game workshop training. Before beginning data collection in the MLW Flagway Game workshop training, I participated in a 2-week (10 day) training with CMLWs from January 22, 2007, to February 2, 2007. This training involved 24 CMLWs and met at YPP headquarters for 4 hours a day, Monday through Friday. YPP instructors led the training session and took part in the developing and facilitation of mathematics curriculum materials and its facilitation. I took part in the CMLW Flagway Game workshop training session to establish my place in this community of CMLW trainers. As a researcher, I was very conscious of my presence in the research site and how that presence changed my interaction in the site. As opposed to being an observer during the CMLW training, who would gained understanding with an *etic* perspective, I engaged in the training as a participant observer to gain an *emic* perspective

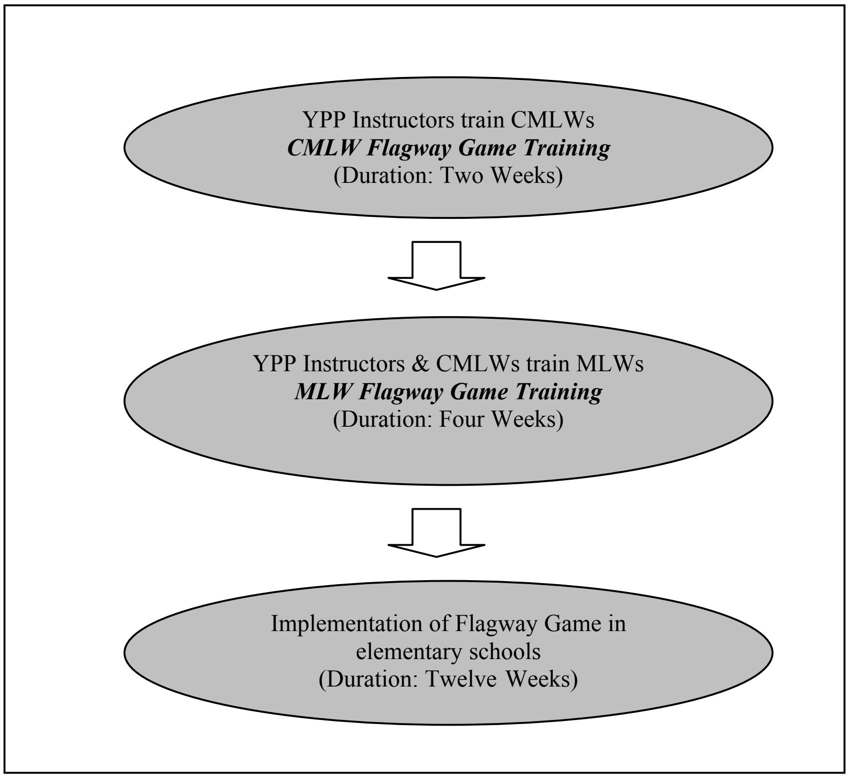


Figure 3.3. The train-the-trainer model used by YPP Chicago.

(Patton, 2002). Interaction with CMLWs in the training was important because I wanted to engage in discussions with them about activities they created and would teach to MLWs. This discussion was important to my understanding of the mathematics they engaged in. I also wanted to understand the mathematics of the Flagway Game. Wenger (1998) reminds us that the three major components of communities of practice are domain, practice, and community. I did not want just to see what happened in CMLW training, I also wanted to feel what it was like to become a CMLW through participation. By becoming a CMLW, I was able to share in their objectives for the training session.

The central focus of the CMLW training during the 2 weeks was for CMLWs to develop a deep understanding of the mathematics of the Flagway Game. The CMLW training consisted of four important components: (a) building CMLWs' mathematics competency with the numbers 2 through 100, (b) building CMLWs' workshop facilitation skills, (c) building CMLWs' awareness of and competency to discuss community social issues, and (d) teaching CMLWs how to effectively play the Flagway Game. Participation in the CMLW training was a requirement for CMLWs before they went to training hubs on their own with MLWs.

Each day of the CMLW Flagway Game training session was structured to include an icebreaker, a teambuilder, several mathematics activities, and a debriefing session. Icebreakers were activities designed for participants to get to know each other better. Teambuilders were activities designed for participants to build their skills to work effectively with each other. Teambuilders also helped to identify strengths and weaknesses in groups so that strategies could be implemented for improvement. Debriefing sessions were a critical component for the organization because they allowed CMLWs to give feedback on the strengths and weaknesses of activities they were introduced to and they planned on using. Through the debriefing process, materials that YPP developed and used were revised for more clarity and effectiveness. More important, CMLWs were able to voice their concerns about issues they might have about training, Flagway Game materials, or implementation of the Flagway Game.

Before CMLWs worked with MLWs, it was important that they develop a high level of proficiency to facilitate all aspects of workshop training. The CMLW training gave the YPP instructors the opportunity to model what effective training would entail so that CMLWs would learn the skills needed to accomplish it at their training hubs.

In Week 1 of the CMLW Flagway Game training, the focus was an introduction of the game through various mathematics activities. Each activity was geared toward developing specific skills with numbers so that players of the Flagway Game would be more mathematically flexible. The mathematics activities were designed to help participants build their understanding of concepts like prime numbers, prime factors, composite numbers, writing prime factors of numbers in algebraic form, and thinking critically about numbers. Each activity was focused on number theory, geared toward building knowledge and understanding of the numbers 2 through 100 (see Appendix A).

Activities throughout the training also consisted of building community awareness of social issues. The CMLWs engaged in activities to help provoke or facilitate thought and discussions about the problems in their communities and ways they could affect change. For example, one activity, Unity of Hands, asked CMLWs to trace their left and right hands, side by side on chart paper. They were then asked to write three things they wanted to see in their community in the left-hand tracing and three things they did not want to see in their community in the right-hand tracing. They were then encouraged to think of themselves as change agents to resolve these issues. In the left-hand tracing, the CMLWs included more community outreach, community leaders, community organizations, positive role models, good schools, and affordable homes. In the right-hand tracing, the CMLWs included gentrification out of the community, liquor stores, prostitution, drugs, and gangs.

In Week 2, the CMLWs worked in groups to prepare for their work with the MLWs. Using many of the mathematics activities they learned as guides, the CMLWs worked together in cohorts consisting of three CMLWs and one YPP instructor to plan and develop materials they would use in their first week with MLWs. Throughout the training, the CMLWs learned to facilitate workshops by doing mock workshops. Mock workshops were conducted to engage the training participants in activities they would use in MLW Flagway Game training sessions. The CMLWs were then given feedback on the strengths and weaknesses of their facilitation and ways they could improve.

Data Collection Site

Abelin Preparatory High School is a neighborhood charter school that is a part of the Chicago Public School system and located on the west side of Chicago. Abelin was opened in 1998 in response to a growing urgency to prepare and to provide young people from the under-resourced neighboring community with skills they needed to enter and successfully complete college. This feature was greatly needed in the community since there were no neighborhood high schools providing academically rigorous curriculum and a supportive environment for students. There were approximately 670 students who attended Abelin from Grades 9 through 12. Ninety-seven percent of the students who attended Abelin are African American, and 3% are Latino. Ninety-two percent of the student population participated in a free and reduced lunch program, and 97% of the students who attended the school resided in neighborhoods on the west side of Chicago.

During the 1960s through 1990, the community that surrounded Abelin experienced economic devastation due to riots following Martin Luther King's assassination in 1968. Many businesses were destroyed and companies disinvested their interest in the community. Consequently, there was a sharp decline in the population and massive job loss (Stean Family Foundation, 2009). According to U.S. Census data (2000), the high school graduation rate was approximately 43.6%. About 5.7% of the residents earned a bachelor's degree or higher. The median household income was approximately $28,203. The percentage of individuals with income below the poverty level was approximately 31.4% as compared to poverty rates in the state of Illinois of approximately 10.7%. According to more recent data, the Steans Family Foundation (2009) cited that 59.4% of the 20 to 24 year olds were jobless and the community had an unemployment rate of 13%. The community continues to be predominantly Black with approximately 94% of African Americans, although there is a growing Hispanic community in the area. While the area continues to be economically depressed, there are signs of community revitalization as evidenced by some re-gentrification and commercial reinvestment.

MLW Flagway game workshop training. As described in chapter 1, there were six training hubs for the MLW Flagway Game Workshop training. The Workshops were conducted after school and for about 3 hours a day, Tuesday through Friday. Although all MLW Flagway Game training sessions were structured to include the same components, each training hub cohort was ultimately responsible for how sessions were organized and conducted at their site. I participated and collected data during the MLW Flagway Game workshop training in Chicago held from February 5, 2007, to March 2, 2007, which included 16 MLWs. The week-by-week description I provide of the MLW Flagway Game training session represents the Abelin Preparatory High School training hub used in this study.

Similar to the CMLW training, the overall focus during the 4 weeks of the MLW training was for MLWs to develop a deep understanding of the Flagway Game. The MLW training had five components; (a) building MLWs' basic mathematics competency with numbers 2 through 100, (b) building MLWs' facilitation skills, (c) building MLWs' awareness of community social issues, (d) teaching MLWs how to effectively play the Flagway Game, and (e) planning for implementation of the Flagway Game at elementary schools. Each day of the MLW Flagway Game training session was also structured to include an icebreaker, a teambuilder, several mathematics activities, and a debriefing session.

In Week 1 of the MLW training, the YPP instructor and CMLWs worked on building rapport with new and returning MLWs. The CMLWs and MLWs engaged in teambuilder exercises to develop team spirit and cooperative working skills. At elementary schools, the CMLWs and MLWs relied on each other to get tasks accomplished. The MLWs were also engaged in critical dialogue about the YPP mission statement, which helped many of the new MLWs better understand the goals of the organization. The CMLWs also introduced the Flagway Game to the MLWs through prime number activities.

In Week 2, the CMLWs and MLWs engaged in activities to raise awareness of issues in the local and broader community. The MLWs discussed topics like wealth distribution among the rich, poor, and middle class; censorship of lyrics in music; social and political activism; and the benefits of mathematics literacy as an organizing tool for implementation of change in neighboring communities. In addition to the community awareness component of the MLW training, the instructor and CMLWs continued to build number sense with the MLWs through other mathematics activities.

In Week 3, the CMLWs continued to introduce mathematics activities to build number sense, but they also started to play the Flagway Game with the MLWs. The MLWs learned how to navigate the Flagway course with a flag to reach the goal. The CMLWs and MLWs also discussed effective coaching of elementary students. The coaching entailed the MLWs conducting mock workshops where they would get feedback from participants in the training session.

In Week 4, the MLWs worked together to plan for implementation of the Flagway Game in elementary schools, using many of the mathematics activities they had learned during the previous 3 weeks. With guidance from the YPP instructor and CMLWs, the MLWs modified mathematics activities to be appropriate for elementary school students. After the MLWs became more comfortable with mathematics activities, they facilitated mock workshops with others to obtain feedback for improvement and effectiveness. One activity the MLWs facilitated was called Prime Hunt. In Prime Hunt, two teams are given a stack of paper, each sheet with random numbers from 2 to 50. Each team is allotted the same amount of time to locate all of the primes in their pile. The team that is able to identify the most primes wins.

Debriefing all activities was also a crucial aspect of the MLW Flagway Game Workshop training. Before the close of each session, the instructor, CMLWs, and MLWs discussed what worked and what did not work for each of the activities completed that day. The direct feedback from the MLWs enabled modifications in planning for the following workshop session.

Research Method

The main reason why an interpretive qualitative case study methodology is used is not only to tell an in-depth story of a person, group, program, subculture or phenomenon, but also to develop conceptual categories “with the intent of analyzing, interpreting, or theorizing” (Merriam, 1998, p. 38). Qualitative methods of inquiry are grounded in the tradition of asking questions to find meaning about reality through others’ personal experiences (Winter, 2000). In particular, using case study methodology allowed me to accomplish the research by answering focused questions, constructing an analysis, and providing detailed descriptions of the case over a short period of time (Hays, 2004).

An interpretative qualitative case study design also facilitated a comprehensive and multi-layered study of the phenomena. I wanted to gain an in-depth view of the CMLWs and MLWs of YPP Chicago. Through observing participant's experiences, I wanted to look closely at what mathematics literacy identities the CMLWs and MLWs developed as they engaged in an aspect of their mathematics literacy work, their Flagway Game training. To understand the experiences of others within unique contexts, qualitative case study methodology is a useful approach for answering focused questions with the aim of extending theory and gaining new and better understanding (Stake, 2000). Furthermore, according to Merriam (1998), "The case study offers a means of investigating complex social units consisting of multiple variables of potential importance in understanding the phenomenon" (p. 41).

To ensure that my research design was well developed, I used Yin's (2003) observation that there are five key components in formulating a quality case study design: (a) the study's research questions; (b) the study's propositions, if any; (c) criteria for interpreting the findings, (d) logic linking the data to the propositions; and (e) choosing the units of analysis. Although all of these components were critical, choosing the unit of analysis was one of the most important parts of the design.

In case study methodology, it is critical that a unit of analysis be carefully selected before the research begins. A unit of analysis is the object of study. It is, as Stake (2000) calls it, the bounded system. For this study, the unit of analysis was the CMLWs and the MLWs. The unit of analysis narrowed my focus to the bounded system in question. For this study, the context was the Flagway Game Workshop training for CMLWs and MLWs of YPP Chicago and how mathematics literacy workers were being prepared for implementation of the Flagway Game. The MLW training session served as the context because I wanted to understand what CMLWs and MLWs do during training and how that training influenced their identities and their understanding of the mathematics used in Flagway. The type of case design that was appropriate for this study was a holistic multiple-case design. I chose this design because from a methodological perspective, multiple-case design allowed replicability. In other words, it allowed me to construct individual cases of participants. For this study, I wanted to look specifically at CMLWs and MLWs of YPP Chicago as objects of study in their community of practice.

YPP Chicago – The Community of Practice

YPP Chicago is a community of approximately 130 mathematics literacy workers, which are CMLWs, MLWs, or instructors. The community consists primarily of different types of students. Some students are high school students, some attend undergraduate institutions, and others are graduates. Membership in YPP Chicago is voluntary. Prospective members are formally solicited at schools and colleges and through after-school initiatives to join the organization. The number of members in the community changes from year to year. Some mathematics literacy workers graduate and leave, and new members enter. Some mathematics literacy workers continue their work with YPP Chicago after they graduate from school because of their connection to the organization and their deep commitment to mathematics literacy work. Through extensive participation, their membership becomes more legitimized over time. What makes the YPP Chicago a community are the shared values and practices that are cultivated among members over time. The students in YPP Chicago attend schools throughout Chicago. They come to the community with a variety of experience, ranging from little to extensive expertise in mathematics, depending on their individual area of study. Despite each member's expertise, YPP Chicago has very specific ways that they engage in mathematics literacy work. A common mission statement unites mathematics literacy workers in YPP Chicago. The mission statement affirms the literacy workers' purpose, inspires members to participate, gives members meaning and a context for their work, and guides their learning and the knowledge they produce. Members in the group also share a commitment to improve young people's understanding of numbers through the Flagway Game and through other mathematics literacy activities they engage in. Mathematics literacy workers also form social bonds through prolonged interactions in the community.

Participants

Participants and Training Hub Selection

A criterion-based selection strategy (deMarrais, 2004) was used to identify four participants for this study, two CMLWs and two MLWs. I describe the selection process for the training hub and CMLWs, and then I describe the selection process for MLWs.

Training hub and CMLW selection. I used the CMLW Flagway Workshop training to identify CMLWs and one high school training hub that I worked with for this study. The three selection criteria were the following: (a) at least one semester of experience with the Flagway Game, (b) returning to the same high school training hub from the previous semester and, (c) attending all sessions of the MLW Flagway Game Workshop training. My rationale for these criteria was that I was concerned that new CMLWs would not have a deep understanding of the Flagway Game, know how to run a structured training session, or have rapport with MLWs from the work done the previous semester. I wanted CMLWs who were familiar with the Flagway curriculum and YPP as an organization because they would be able to provide insight and perspective from their experience. There was one cohort of CMLWs and one training hub that met these criteria. I decided to work at the high school training hub, Abelin Preparatory High

School, because it was the only high school site in which there were CMLWs returning from the previous semester to facilitate MLW Flagway Game training sessions. Of the 24 CMLWs who participated in the training session, 2 were asked and agreed to be participants in this study. The reason was that several of the CMLWs were new to YPP, so they did not meet the selection criteria. The two participants selected were the only CMLWs that met the criteria.

MLW selection. Before I selected MLWs for the study, I wanted to gather background data on their past mathematical experiences in high school. I wanted to know the mathematics courses they had taken, their comfort level in mathematics, and their past successes in mathematics. When the MLW Flagway Game Workshop training began at Abelin, I administered surveys to all 13 MLWs to gather this information. The survey included multiple-choice questions and free-response questions (see Appendix B). The free-response questions asked participants about the significance in doing mathematics literacy work and the number of years they had spent in YPP. The purpose was to obtain an initial sense of MLWs' perception of their mathematical competency and a preliminary understanding of their motivation for doing mathematics literacy work. More important, because some of the participants were high school students, the survey data enabled me to get a sense of their willingness to disclose information about themselves and aspects of their mathematics experience.

In addition to the training hub and CMLW selection criteria previously described, I also developed criteria for selecting the MLWs. The MLWs were chosen according to four criteria: (a) at least one semester of experience in YPP, (b) returning to the same high school training hub from the previous semester, (c) attending all sessions of the MLW Flagway Game workshop training, and (d) expressing a moderate to high comfort level with mathematics. Of the 13 MLWs surveyed, 3 did not want to participate in the study; 4 did not meet the criteria for the study; 6 met the criteria, but 2 were selected to participate in this study. The reason was that all the other participants dropped out of the study before the workshop training was completed.

Research Design

Data Collection

The work of the CMLWs and MLWs in workshop training sessions included their interaction with one another as they developed and learned about the mathematics activities used in elementary schools. To capture mathematics literacy identity and their understanding of the mathematics used to play Flagway, I used three data collection strategies: (a) observation data, (b) interview data, and (c) archival data. A description of each data source is given below.

Observation data. The first data source was observation. My goal in collecting these data was to observe the levels of engagement the CMLWs and MLWs had in their community of practice, the workshop training session. Considering that the interaction between CMLWs and MLWs together occurred in one setting over a 4-week period, this context was quite revealing about them. During the workshop training, I observed several types of interactions. I first observed how CMLWs and MLWs interacted with one another. I asked questions like, What kinds of relationships are being formed between the CMLWs and MLWs in this workshop training? I also asked, How well are the CMLWs and MLWs learning and understanding the mathematics activities of the Flagway Game through their interaction? I also observed the levels of engagement in the workshop between the CMLWs and MLWs and the types of contributions the participants made to discussions and during daily activities. I documented participant responses in discussions about mathematics and social justice issues. The observations enabled me to structure questions that I would later ask the participants in interviews. Total observation time for this study was approximately 92 hours.

Interview data. The second data sources were two semi-structured open-ended interviews (see Appendices C and D for the interview protocols). The purpose of the interviews was to see how participants described their experiences in YPP and what they thought they learned about themselves and numbers as a result of their participation. The first interview focused specifically on obtaining information about each participant and the impetus for becoming a part of YPP. I wanted to know what influences shaped the CMLWs and MLWs' decision to do mathematics literacy work and the changes they had seen in themselves as a consequence of being a part of YPP. I also wanted the participants to reflect on past experiences in YPP that were memorable to them.

The second interview had two goals. The first goal was to engage participants with some of the number theory concepts they learned during the workshop training. I wanted to investigate their level of understanding of how to categorize numbers in the Flagway Game. To accomplish this goal, I engaged the participants in three mathematical tasks that helped them to articulate their thinking on how to categorize numbers used in the Flagway Game. To save time, I decided to omit the numbers 22 through 34. I asked the participants the following questions for the mathematical tasks:

1. Let's consider the first twenty numbers 2 through 21. Can you list these numbers for me and next to them the colors they correspond to? Explain your reasoning for each.

2. Can you repeat this for the numbers 35 through 50? Explain your reasoning for each.

3. Can you write the algebraic form for each of these numbers (i.e., 2 thru 21 and 35 thru 50)? Explain your reasoning for each.

    a. What theories have you developed about the numbers 2 – 50 as it relates to the categories Red, Yellow, and Blue? Explain your reasoning for each.

For this study, a mathematical task as described by Smith and Stein (1998) is a task that engages students in high levels of cognitive thinking and reasoning. I used Smith and Stein's mathematical task framework as a guide for creating the three tasks used in the second interview. Smith and Stein outlined six items that should be required when doing mathematical tasks:

- Require complex and non-algorithmic thinking (i.e., there is not a predictable, well-rehearsed approach or pathway explicitly suggested by the task, task instructions, or worked-out example)
- Require students to explore and understand the nature of mathematical concepts, processes, or relationships
- Demand self-monitoring or self-regulation of cognitive processes
- Require students to access relevant knowledge and experiences and make appropriate use of them in working through the task
- Require student to analyze the task and actively examine task constraints that may limit possible solution strategies or solutions
- Require considerable cognitive effort and may involve some level of anxiety for the student due to the unpredictable nature of the solution process required. (p. 348)

I decided to ask the participants about the numbers 2 through 21 because they were somewhat familiar with this group of numbers, and I wanted see how they would explain the classification in their own words. The numbers 34 through 50 were not as familiar to the participants, and I wanted to see what classifications they would have. These mathematical tasks were followed by reflective questions for the CMLWs and MLWs about what remained a challenge and what they found comfortable to articulate concerning the number theory concepts and categorization of numbers in the Flagway Game. I also wanted to know the mathematical goals (if any) the participants had developed for themselves in mathematics as a result of engaging in the workshop training. Mathematical goals are priorities that CMLWs and MLWs make for themselves regarding mathematics and their work with elementary students.

The second goal of the second interview was to understand how the CMLWs and MLWs saw themselves grow in mathematics as a result of their participation in YPP and their implementation of the Flagway Game from the previous semester to the current semester.

Each interview was audiotaped and transcribed. The first interview was conducted at the close of the third week of training. The second interview was conducted at the close of the last week of training.

Archival data. The third data source was archival. I gathered artifacts from each training context over the 6-week period. The archival data included training materials, mathematics activities, the CMLWs' and MLWs' notes from planning and training sessions, the MLWs' written work, and the CMLWs and MLWs' reflections about their experience and work in YPP. These artifacts assisted me in formulating interview questions.

Data Analysis

Thematic Analysis

The bulk of data collected for the multiple-case study were from interviews, and the approach that I used to analyze these data was thematic analysis (Ezzy, 2002). Thematic analysis relies on coding to identify themes and concepts that are in the data. Along with Ezzy, who gave brief description of this process, Strauss and Corbin (1990) describe the three important stages of the coding process: (a) open coding, (b) axial coding, and (c) selective coding.

In the open-coding process, Strauss and Corbin (1990) identified two steps: data conceptualization and data categorization. Deep familiarization with the data occurred when I "[opened] up the text and [exposed] the thoughts, ideas, and meanings contained therein" (p.

102). I closely scrutinized each line of the interview text, checking for similarities and differences in the text to formulate concepts that represented specific phenomena. Strauss and Corbin suggest that this is the most detailed type of analysis. I then created categories that pertained to each phenomenon. Throughout this process, I took notes that identified preliminary guesses and intuitions.

During axial coding, data are reconstructed, "put back together in new ways after open coding, by making connections between categories" (Strauss & Corbin, 1990, p. 96). In this stage, the coding process was specified more closely using a coding paradigm model. Each causal condition was connected to some phenomenon, which was then linked to categories indicating contexts, conditions, actions or interactional strategies, and consequences. This method allowed me to think about the data in a structured way and formulate more complex relationships between categories. Figure 3.4 illustrates a simplified representation of the paradigm model used in the analysis.

(A) Causal Conditions → (B) Phenomenon → (C) Context →

(D) Intervening conditions → (E) Action/Interaction Strategies → (F) Consequences

Figure 3.4. Paradigm model used in axial coding (from Strauss & Corbin, 1990, p. 99).

During the selective coding stage, which is also known as theoretical coding. I identified a core category or a central story around which the analysis focused. Core codes and any others identified were examined to uncover relationships. I then compared schemes with pre-existing theory. The coding process was completed once saturation took place with underlying theory (Ezzy, 2002). Saturation occurred when no other codes or categories were found.

To aid in data management and coding, I entered data into a word-processing software and used the step-by-step analysis method developed by Ruona (2005). Once all interviews were transcribed, they were arranged into a six-column table in which the interview text was the focal point. Each table had column headers identifying codes, participant identification numbers, interview question numbers, interview questions asked, participant responses to those questions, and notes on initial observations made in the interview text.

Considering that thematic analysis was the overarching approach used for the multiple-case study, there were two stages that were used in the analysis process: the within-case analysis and the cross-case analysis (Merriam, 1998).

Within-case analysis procedures. I first focused on refining coding schemes one interview transcript at a time. This process was completed with the first interview for each of the four participants. I then completed this process with the second interview for each of the four participants. I first read through each transcript repeatedly to become familiar with the interview text. I then separated the text into meaningful sections by creating additional rows in the table. I added notes to clarify any observations made. This process was repeated several times. After familiarization began with each interview, I began creating preliminary categories and coding schemes for each participant (see Appendix E). This process was iterative and continued throughout the analysis refining categories and generating new meaning in the data. Themes were finally developed for each participant. I then created a comprehensive case study for participants based on the data. For each case study, I strove to tell the participants individual story.

Cross-case analysis procedures. Taken all the transcriptions together, once saturation of the data occurred and no more codes could be applied, I consolidated all interview text into one table. By merging the coded data into one table, I could continue the interpretation process and sort the data in a number of ways. Merriam (1998) points out that "a qualitative, inductive, multicase study seeks to build abstractions across cases" (p. 195). I sorted coded data that were similar across participants to see what common themes were illuminated (Appendix F). I also looked for similarities and differences between the types of participants (e.g., CMLWs and MLWs). Although each individual case varied in their detail, there were some common themes across participants identified. Strauss and Corbin's (1990) method of analysis along with Ruona's (2005) were useful in organizing the data so that a meaningful analysis could take place.

Remaining Data Sources

I analyzed the remainder of the data sources, observation data, archival data, and participant reflections qualitatively by visual inspection. I looked at these data sources to search for supporting materials for themes identified from the interview data. A summary of how each research question was analyzed is presented in Table 3.1.

Validity and Reliability

To ensure the rigor of qualitative inquiry, Merriam (1998) suggests that internal validity, external validity, and reliability be carefully considered as research is conducted. Merriam first describes the importance of validity when conducting qualitative research. Validity has two components: internal validity and external validity. Merriam states that internal validity "deals with the question of how research findings match reality" (p. 201). In other words, how well did the meaning one constructed about reality match what was actually there? In qualitative research, one goal is to observe how well others construct reality and then provide some interpretation of it. To enhance internal validity, Merriam recommends six strategies: triangulation, member checks, long-term observation, peer examination, participatory or collaborative modes of research, and researcher's biases. Table 3.2 provides the six strategies with descriptions and indicates how they were used in this study.

External validity is "concerned with the extent to which the findings of one study can be applied to other situations" (Merriam, 1998, p. 207). In other words, how well can the findings be generalized? Merriam proposes three strategies for approaching external validity: rich, thick descriptions; typicality or modal category; and multisite designs. Rich, thick descriptions are necessary to describe the research situation and to also give background on how findings were derived. In this study, detailed descriptions were used to illustrate the research context for the Flagway Game and workshop training because its structure may look different from site to site and across cities. Typicality or modal category describes how distinctive the research topic in question can be compared to other situations. Because this study sought to tell the story of four people in one YPP site in Chicago, I did not intend for the findings to be generalized across all YPP Chicago sites. Finally, multisite designs use several sites, cases, or situations to study the phenomenon in question. For this study, four cases of two CMLWs and two MLWs were created to tell the story of what identies they had and what mathematics they understood as a result of their work in Flagway Game trainings. Both CMLWs and MLWs were used in this study because both play significant roles in YPP. Knowledge about CMLWs and MLWs provided different perspectives on the notion of identity with high school and college mathematics literacy workers.

Rigorous qualitative research also depends on the reliability of the findings in the study. Merriam (1998) describes reliability as the "extent to which research findings can be replicated" (p. 205). Because of the nature of qualitative research, replicability may be difficult to achieve. As Merriam suggests, it presupposes a one-dimensional reality that everyone shares. Producing

Table 3.1. Relationship Between Research Questions, Data Sources, and Method of Analysis

Research Questions	Data Sources	Analysis
1. What identities do African American college mathematics literacy workers and high school mathematics literacy workers have of the Young People's Project Chicago, in the context of the Flagway Game training? a. What led African American college mathematics literacy workers and high school mathematics literacy workers to participate in the Young People's Project Chicago? b. What role do African American college mathematics literacy workers and high school mathematics literacy workers see themselves having in their local communities?	- Observations - Interviews - Archival data - Personal reflections	- Thematic analysis - Visual inspection
2. What are the mathematics strategies used by college mathematics literacy workers and high school mathematics literacy workers in number categorization of the Flagway Game and their understanding of these number concepts?	- Observations - Interviews - Mathematical tasks	- Thematic analysis - Visual inspection

one kind of reality may not be a reasonable goal for qualitative research. Instead of aiming for replicability, Merriam recommends, as do other scholars (Lincoln & Guba, 1985; Yin, 2003) that one should work towards dependability or consistency in results. Merriam also argues, "The question then is not whether findings will be found again but whether the results are consistent with the data collected" (p. 206). Merriam suggests three techniques to ensure that results are dependable: the researcher's position, triangulation, and audit trails.

Table 3.2. Strategies for Enhancing Internal Validity

Strategies for Enhancing Internal Validity	Ways in Which Strategies Were Utilized to Enhance Internal Validity
1) *Triangulation* – Using multiple investigators, multiple sources of data, or multiple methods to confirm the emerging findings.	1) I used multiple sources to gather data for this study; they included archival data, interview data, survey data, and observation data.
2) *Member Checks* – Taking data and tentative interpreations back to the people from whom they were derived and asking them if the results are plausible.	2) I asked participants to review findings of the study. I asked them to respond to the credibility of the findings.
3) *Long-term Observaiton* – At the research site or repeated observations of the same phenomenon — gathering data over a period of time in order to increase the validity of the findings.	3) The observations for this study took 6 weeks. The total observation time was appproximately 92 hours.
4) *Peer Examination* – Asking colleagues to comment on the findings as they emerge.	4) I met periodically with my dissertation advisor to obtain feedback about findings as they emerged in the data.
5) *Participatory or Collaborative Modes of Research* – Involving participants in all phases or research from conceptualizing the study to writing up the findings.	5) Periodically spoke with study participants throughout the study to inform them on any changes to study or any additional materials needed.
6) *Researcher's Biases* – Clarifying the resesarcher's assumptions worldview, and theoretical orientation at the outset of the study.	6) Addressed in the section, How the Study Began, in chapter 1.

The investigator's position describes any hypotheses and theories behind the study, the researcher's position, and the criteria for selecting informants of the study along with their descriptions. My position also included the social context for which data were collected (Merriam, 1998). My position was described as it was taken (included in chapter 1) and describes my point of view as it pertains to this study. Triangulation of data strengthens reliability and internal validity of data collection and analysis (Merriam, 1998). In this study multiple forms of data were used in the collection and the analysis process. Finally, an audit trail, is the process the researcher uses to describe the decisions made throughout the research process. In this study and in this chapter, detailed descriptions of data collection and data analyis are provided as part of the my audit trail. All three strategies were used to strengthen external validity for this study.

Ethical Considerations

In addition to the issues of validity and reliablity that must be addressed in any study, research should also be conducted in an ethical manner. Conducting research in an ethical manner primarily involves the privacy and protection of participants during the data collection and the dissemination process (Merriam, 1998). Merriam explains that data collection may have some "unanticipated long-term effects" (p. 214) that a researcher should be aware of. For instance, in the interviewing process, participants may reveal information about themselves they did not intend to. Furthermore, observations, whether participants are aware of them or not, also pose some ethical concerns. During the observation process, researchers must be sure to be forthcoming about their intentions as they relate to their presence in the research site. Whether participants are made aware of the researcher's observations or whether they are concealed, a researcher's presence may change the activities being studied. During dissemination, researchers must also be conscious not to reveal the identity of participants unless they have consented. Finally, researchers should be mindful of the manner in which they have presented participants. That is, have they been presented positively or negatively?

For this study, I considered ethical issues throughout the research process. First, approval to conduct this study was granted by an Institutional Review Board. Second, I was granted consent to conduct observations at the research site where participants would be fully aware of my presence. Third, each participant was provided consent forms that indicated that his or her participation in this study was completely voluntary basis and could be terminated at any time if he or she wished to do so. Fourth, each participant was contacted and asked to review participant profiles and other research findings documented about them in this study. Finally, this study was shared to the research community in an ethical manner. Psuedonyms were used to disguise the identities of the participants and the data collection site.

CHAPTER 4

FINDINGS AND ANALYSIS OF FINDINGS

> The mission of the Young People's Project is to use mathematics literacy as a tool to develop young leaders and organizers who radically change the quality of education and quality of life in their communities so that all children have the opportunity to reach their full human potential. (O. Moses, 2006, p. 5)

Within-Case Analysis - The Case Studies

The purpose of this study was to examine how the experiences of African American college mathematics literacy workers (CMLWs) and high school mathematics literacy workers (MLWs) within a community of practice, namely the Young People's Project (YPP) Chicago, influence the identities they have and inform how they categorize numbers used in the Flagway Game. The research questions and their subsidiary questions are addressed in this chapter:

1. What identities do African American college mathematics literacy workers and high school mathematics literacy workers have of the Young People's Project Chicago, in the context of the Flagway Game training?

    a. What led African American college mathematics literacy workers and high school mathematics literacy workers to participate in the Young People's Project Chicago?

    b. What role do African American college mathematics literacy workers and high school mathematics literacy workers see themselves having in their local communities?

2. What are the mathematics strategies used by college mathematics literacy workers and high school mathematics literacy workers in number categorization of the Flagway Game and their understanding of these number concepts?

This chapter provides within-case analysis of findings on the four participants: two African American college mathematics literacy workers, Naomi and DeMarcus, and two African American high school mathematics literacy workers, Charlene and Phil. The four case studies provide details on the identities of the CMLWs and MLWs in the context of the Flagway training and their work implementing the Flagway Game at elementary schools. The data corpus includes observations, interviews, student work from mathematical tasks, participant reflections, and archival data. To answer the research questions, for each case study the following sections are included: A profile in depth of the participant that includes his or her (a) view of mathematics, (b) impetus for becoming a part of the Young People's Project, (c) view of mathematics literacy, and (d) interpretation of the Young People's Project mission statement (the epigraph for this chapter) and how they sought to embody the expectations of the mission in their mathematics literacy work. The mission statement was developed in 2006 by YPP members and provided a framework for their practice as they engaged in mathematics literacy work. Each case study also includes the identities of the participant as a result of his or her work with the Flagway Game, which is organized into several themes. The participant's mathematics strategies for understanding the categorization of numbers are also provided in each case study and are linked to the identities. At the end of each case study, a summary is provided. In this chapter, cross-case analysis of identity and mathematics strategies used in the Flagway Game are also presented along with tables that summarize the themes as it pertains to the two main research questions.

During my interviews with the CMLWs and MLWs, I appreciated their willingness to share their experiences and the depth of their backgrounds. There was a 6-year age difference between participants, so it was not surprising that the CMLWs gave more details than the MLWs about their experiences and background information. This difference can also be attributed to a difference in the time that we spent together. I was able to get to know the CMLWs better through the CMLW training and the MLW training, car rides I offered them to their homes, and other informal opportunities to interact. The MLWs were full-time high school students with limited interaction time outside of the MLW training and other extracurricular activities in which they participated. They arrived at Abelin for their first class, which began at 7:00 am, and left at

7:00 pm after the Flagway training was over. Even with these constraints, I strove for detailed descriptions of all participants.

Two of the case studies include dialogue between me and the participant to clarify the participant's thoughts. Figure 4.1 is a key to these transcriptions.

I	Me the interviewer
C	Charlene
P	Phil
….	a brief pause or a sentence trailing off
[ ]	text inserted by me for clarification

Figure 4.1. Key to transcriptions.

The Case of Naomi

Profile

Naomi, a female African American college mathematics literacy worker and undergraduate student at New University, enjoyed working with young people of all ages. She had the official title of an instructor, which can be described as a lead CMLW in YPP, where she worked closely with other CMLWs teaching and developing curriculum for Flagway training. Naomi's initial impetus for starting her work with YPP was the enjoyment she got working with others. She also had a passion for the arts and humanities. This passion gave her the opportunity to explore her creative side through writing, dancing, and performing in musical productions.

Naomi possessed a very strong willingness to do mathematics. This willingness was demonstrated by her overall view of mathematics, which she described as "a pretty positive one." Naomi understood that many people often struggle with mathematics, and even she did from time to time. But she chose to "look at mathematics in a positive way" because, she thought, "it's fun." Naomi believed that mathematics provides space for exploration of new ideas "even though it has a set answer… because you are discovering the answer." In our first interview she stated, "I just see the broadness of math…. There's still a lot to discover about math, still things about math and science that we don't know."

Naomi had a calm disposition and prided herself on her patience and empathy with the CMLWs and MLWs that she worked with. She explained that these two qualities were essential for all mathematics literacy workers to have and to be effective at outreach work with elementary students. Her patience and empathy had been cultivated during her time working with nonprofit organizations centered on youth. Naomi had worked with nonprofit and after-school programs for the previous 7 years. One of the nonprofit programs, Mind Rap, incorporated hip-hop music, African History, and African American History to teach mathematics and science skills to underprivileged students and to boost their self-esteem. Mind Rap, is based on the notion that hip-hop is a product of the community and that students respond positively to hip-hop music. Through Mind Rap, Naomi became familiar with YPP. Once a week in Mind Rap she worked with a group of students who were MLWs in YPP. Naomi decided to work with the organization during a summer so that she could better understand the students, their experiences in YPP, and the mathematics they were learning. The work was so exciting to her she decided to continue as a CMLW.

One important aspect of YPP outreach work is the mathematics literacy workers' understanding and execution of mathematics literacy as a goal. Naomi's view of mathematics literacy included not just access to mathematics but also helping those who had been undereducated do mathematics. Naomi believed that the work that YPP does is a way of helping students in schools who have difficulty with mathematics obtain mathematics literacy. She explained:

> I mean I think math literacy is having the ability…to do math. I think when we say, "Well, these people don't have access to math," it's not necessarily like I don't have the ability to open a textbook and read it myself. Math literacy means not just the access but being able to do it.… Maybe it's two parts, like having access to it and then having the literacy to do it. So that means, you know, maybe this school is not providing that math literacy. Maybe the people who are below certain rates on their testing just get lost in the system, which we've seen over and over again. They graduate and can't do the math. So we need extra things in place. We need the Algebra Project in the schools. We need [the] YPP project after school. We need to go out to the elementary schools. It's just sort of picking up where, okay, we can give access, but now we need to give literacy. We need to make sure that the students are able to do it. (February 19, 2007)

Naomi further explained that she believed YPP compliments what was already happening in schools. More important, she believed that through the AP and the YPP, students got the opportunity to deepen what they knew about numbers and have experiences in mathematics beyond the traditional curriculum. Naomi explained:

> The [schools], they're going to continue teaching what they're teaching as long as certain things are in place. So as long as Illinois students have to take this test to pass, the teachers are still going to teach [to] the test. So YPP sort of just compliments that. I think that if I were a student in school, and I was an elementary school kid, and I had this epiphany about the way I thought about numbers, that just compliments what I am already learning in school and maybe opening my eyes to different things. I think [YPP] works in that way. (February 19, 2007)

Naomi interpreted the YPP mission statement like an activist. She saw herself and the other mathematics literacy workers as individuals who could be proactive in helping others understand how mathematics was perceived in the community and then do something about changing it. Naomi reflected on the mission statement and came up with the following explanation of its meaning:

> Okay, well, I've thought about it before, and I contextualize the entire statement, you know, radically changing the quality of education, being leaders, pushing people to their full human potential, not just your students, yourself. Everybody involved with the Project and I contextualize the entire mission statement with Bob Moses' bigger picture

> of being a civil rights activist and mathematics being a civil right. And me realizing that, okay, having access to education is a *right* [italics my emphasis]. If I don't have access to education, like my government or my public or whatever should not hold that access from me. I should be able to access education so that I can exercise my full human potential. [In] a lot of minority communities and low-income communities, that's not what's happening. And so that's what I see the mission of the Young People's Project. We spread ourselves, we're like a spider.… We started off with the trainers, then the instructors, and then the CMLWs, and then we spread ourselves all around all areas of Chicago. And I think I just really think that it [was] sort of supposed to be a movement. That's how I interpret it. Like the word *radical* [italics my emphasis] to me means we are not taking this anymore. We are not going to sit here and let our students just continue to be below math literacy rates. Like we're not going to do it. That's what radical means to me. I think the [words] *radical* and *full human potential* really, you know, stick out to me in the mission. (February 19, 2007, emphasis added)

In one of Naomi's reflections about her work at Abelin, she stated the following about the social justice aspect of YPP work:

> YPP is a program created to help make a change in the individual lives of several students of all different ages. We are out here trying to create a community where knowledge will trump violence and create power. (Personal reflection, May 2008)

Identity

Role Model in Flagway Training

Naomi had the identity of a role model in Flagway training. An identity of a role model included Naomi exhibiting specific practices of leadership, ownership, and guidance in training the MLWs or their work implementing the Flagway Game. In this study, a *role model* is defined as a person who served as an exemplar of positive behavior in one or more contexts and demonstrates leadership and guidance to others. The following discussion explains how this theme emerged in Naomi's data.

Naomi was the person to whom CMLWs and MLWs deferred when they were confused or needed direction on mathematics activities. She looked at her role in YPP as a form of leadership, mentorship, and guidance to other students she worked with in order to help them understand the mathematics used in the Flagway Game. She believed that possessing the ability to improvise, demonstrating patience, and showing ownership of mathematics literacy work overall were some of the key components of an effective mathematics literacy worker. She often felt that she had to model this ability for the other CMLWs and MLWs. As Naomi suggested, “If you don’t possess those things, you’re not going to enjoy the experience because you are gonna be like, Why isn’t this working?” In her work she strove to embody those characteristics. One way her identity of a role model was exemplified was in her ability to internalize mathematics literacy work, make it her own, and be flexible in the way she communicated mathematical concepts to the CMLWs and MLWs. Through modeling, Naomi consistently demonstrated these qualities in her practice with her peers and encouraged others to think about ways they could improve these skills for themselves.

During training, the MLWs had an easy time identifying prime numbers but a more challenging time articulating the definition of a prime number and a prime factor. To help with their understanding in one of the training sessions, Naomi initiated a discussion and activity to engage the group so they would have to distinguish the difference between a prime number and a prime factor. She wrote the following question on the board:

> Read the definition and put a tally mark next to the [one] that you think is most appropriate. What is a prime factor?
> 1. The only two numbers that multiply to get a prime are 1 and itself.
> 2. A prime number is a number that is only divisible by 1 and itself. What would this look like?
> 3. A number that has exactly two factors, 1 and itself. What are the factors of 5?
> 4. A number that can only be multiplied by 1 and itself … in order to equal the number. (February 20, 2007)

For each of the definitions above, Naomi asked the group to give examples of numbers that satisfied the definition. She recognized that the MLWs had a difficult time distinguishing between these two concepts and took it upon herself to engage them in discussion to understand their thinking. She also wanted to demonstrate to the CMLWs that you have to improvise in training when a concept needs further exploration. By taking the lead in the discussion and changing the direction of the training for that short time, Naomi demonstrated one of the most important skills she believed that CMLWs and MLWs should embody: improvisation. Moreover, by creating a discussion around prime numbers and prime factorization, Naomi was able to show the CMLWs which concepts the MLWs needed to spend more time strengthening. Naomi stated, “You can’t teach the same thing in the same way to everybody …and that’s why improvisation is really important.”

Although Naomi looked at herself and others saw her as an role model in Flagway training, she at times rejected that identity because she believed that mathematics literacy workers were too dependent on her input and not dependent enough on their own ability and ideas. Naomi explained:

> I think they think that I know everything. That’s not the case. I just appear [to] because I can improvise well, and … I can look at something and figure out how to implement it. It looks like I’ve sat with this material for years …. This curriculum was just created. So I am on the same page as them …. But I don’t think they see that. I think they look at me as like Naomi’s all-knowing: “We don’t know what to do, Naomi, help us.” (February 19, 2007)

I asked Naomi why she believed that mathematics literacy workers thought that she knew everything about the curriculum. Her response was as follows:

> I think it’s because I have the ability to look at something and say, “This is what needs to happen.” …I could look at the lesson, at the module, and say, “Okay, here’s a good idea.” And I keep telling them.… ”It’s not like I’ve done this lesson before, I’ve never taught this. I’ve never played this game in my life.”… So I think, like, I just have like a good ability to … get it done. I am very creative, and I know how to work with students. They’re doubting themselves [I] guess because they feel like they can’t do that. And I feel like they think I played some part in creating this or something. (February 19, 2007)

Agent of Change

An agent of change was another theme that emerged from Naomi’s data. In this study an *agent of change* was defined as someone who purposely worked toward creating some kind of social, cultural, or behavioral change in society or in others through his or her work or actions. Naomi described her role in the Young People's Project as improving the welfare of others, working for social justice, and being an activist. This role was linked to her future pursuits in education.

Naomi said that she had a long-term goal of becoming "some sort of humanitarian" and wished to continue working with nonprofit organizations. She also demonstrated a level of social consciousness and awareness of the problems in schools and how she could play an active role in addressing them. She explained:

> Whether it be I start teaching again through other … nonprofit organizations or working for human rights campaigns, or working for social change, social policy, but as long as it is something fun … I just have to make changes. It like hurts me so much … all of this stuff that people can be doing. How can you not be doing something? So I already know, my life has proven over and over again.… I know I want to make a change, I know I need to be there. I know I can't ignore it. I can't sit here knowing that students aren't graduating. Knowing that … thousands of kids are being held back.… I can't do it. So I know that I am gonna be involved in some way. (February 19, 2007)

Naomi also embodied being an agent of change in that she understood that her work as a CMLW was broader than just the Flagway Game. She believed that her role was to encourage other students to take ownership of the issues they saw around them outside of the training and the classroom so that they could go into their own communities and create change. She explained:

> I feel like my purpose, I guess on a micro-level, is to make sure that Abelin can survive.… I can leave, and Abelin will still be a functioning site with students who are impacted in a positive way, that they felt like they gained something and that they also gave something back to the community. So I guess on a broader scale, it's being able to affect those students in a way that they're inspired to do something in their community, or they feel like they have done something to their community or in their communities. (February 19, 2007)

Naomi also explained that although playing the Flagway Game was fun and enjoyable for CMLWs, MLWs, and elementary children, she was working on a broader purpose for mathematics literacy. Naomi described a realization that she had while working with another program, which was echoed in her work with Flagway. She stated,

> I think I really realized this when I was working with Mind Rap. Just the importance of the math and like why it's important that we are doing this with the students. It's not just, "Oh, we want them to think critically about numbers," but it's important. Like we're just not doing it for testing or for trial and error or for maybe this might work. It's important that students have access to math. It's like one of the most assumed goals of YPP that this work is important, and it's important for us to grant access to math to all these students. (February 28, 2007)

Naomi found herself often reinforcing to mathematics literacy workers the purpose of the work they do. She would say to them, "I want you guys to realize that it's about the way we think about numbers." She further explained,

> Like I feel like I had to say that so many times last session, and I don't have to say it that much this session…. "But I know you're frustrated. You think the students aren't gonna learn this, but it is okay.… We're not gonna get this lesson in on time. Did they or did they not think critically about their numbers? Did they or did they not sit down with that number and write down thoughts about it, think about it, vocalize their thoughts about it through these games?" Cause that's, I think that's a big part of how Bob Moses wants to like instill math literacy by changing the way we think about math. So that's at the top of my priority list, and I think that it was really really huge last session 'cause people just didn't get it. But this time around I don't think I really had to bring it up that much, 'cause I think we're all on the same page. (February 19, 2007)

Naomi ultimately believed that she had some impact on the MLWs at Abelin. She believed that the experiences the MLWs had in Flagway training with YPP from the previous semester inspired them to return the following semester. She stated:

> Almost all of my kids returned. We only have four new students.… So to me something happened, and I realized that I had an effect. I realized that some of the students actually like being here…. So something happened. I made some sort of change. (February 19, 2007)

Confident Doer of Mathematics

Naomi possessed an inherent comfort level in doing mathematics. The data suggest that in many respects, Naomi was a confident doer of mathematics as a result of her past schooling experience or being a part of YPP. A *confident doer of mathematics* was defined as an individual who came to YPP confident in his or her ability to do mathematics.

Naomi thought she was intrinsically motivated to do mathematics. She talked about possessing a very strong disposition for engagement in mathematics from her schooling experience before she began her work in YPP. She believed that she could do mathematics easily and that she was good at the subject. Working with Flagway provided her further interest in engagement in mathematics. In high school, Naomi did well in mathematics as demonstrated by a national mathematics competition she competed in and won. Through opportunities that were provided to her by winning the competition, she understood that possessing strong mathematics skills was an invaluable tool. She further clarified,

> It's like so [important] for minorities to be skilled in that area because it allows them to excel.… It opens a lot of doors. Like if I hadn't won that competition. I got a two thousand dollar scholarship. I got a laptop.… Just so many doors, so many opportunities, just for, you know, my math skills. And so, it's really important. (February 19, 2007)

Naomi also made the point that she did not hesitate to do mathematics even if it required more thinking time of her than others. She stated, "I really think… I enjoy math, and I like doing math, and I love discovering it, and I love figuring stuff out…. And I think coming from that standpoint … the fact that it takes me longer to do math, and I'm still not intimidated by it."

Mathematics Strategies and Understanding of Number Concepts

Naomi demonstrated various levels of understanding of how to categorize the numbers used in the Flagway Game. I describe what understanding Naomi displayed as it related to categorization of numbers. In so doing, I also describe how Naomi thought the work with Flagway enhanced her own understanding of numbers. Two major themes were revealed in Naomi's data: memorization for color association and flexibility with numbers.

Memorization for Color Association

Naomi used two memorization strategies to categorize some of the numbers from 2 to 21 and from 35 to 50 in the Flagway Game. In the first strategy, Naomi associated a number in the Flagway Game with its respective color. She explained that if the objective was to find a color output for a number as opposed to its algebraic form, she would quickly recall general facts that she remembered about the color categories as opposed to the mathematical definition of each category. She explained:

> I wasn't even necessarily thinking in terms of even number of prime factors [or] odd number of prime factors. I was just thinking in terms of, okay, all the primes go in red plus thirty, plus like a couple of [the] other numbers and then all of the, any number that has some sort of like…A^2, A^3, I mean like 2^2, that has anything like that, would be in yellow. And then pretty much anything where you multiply two things will go in blue. (February 28, 2007)

Naomi also clarified that because she served as a judge in Flagway tournaments it was easy to train herself to recall color categories for 2 through 10. Naomi further clarified:

> So it's easy for me to be like two through five, seven, eleven: automatically red.…I'm putting those numbers there because I'm thinking the primes, all the primes, are gonna be in red. So it's really easy for me to do that. So, I guess the connection I'm making is that like…when I see those numbers, I see the colors. Like when I see two, three, five, seven, and eleven, I see red. When I see six and ten, I see blue.…The connection between the math isn't really there as much for those numbers. (February 28, 2007)

In other words, Naomi had different goals when categorizing numbers. If her goal was to find the algebraic form of a number, then it was important to break the number down into its prime factors (e.g., $18 = 2 \times 9 = 2 \times 3 \times 3$ can also be written as $A \times B \times B$ *or* $A \times B^2$). If her goal was to determine the color output, then she factored a number *enough* to determine its color category (e.g., $18 = 2 \times 9$, and since 9 is a perfect square, 18 is in the yellow category).

Naomi demonstrated this thinking in one of the tasks she was asked to do. In her work she wrote 2 through 21 and the color associated with each of them. Included in her work, she also wrote some of the categorization rules to remind her of which type of numbers go into which category (Figure 4.2). For 35 through 50, she also wrote the color, but for some of those numbers she wrote her mental arithmetic at the side of the paper because the number-color association did not come as easily to her (Figure 4.3).

Naomi also employed a second memorization strategy that she did not use often. Because she knew the prime factorization definitions of the three color categories, she used this knowledge for determining which categories certain numbers should be placed in. Naomi was asked if she ever broke numbers into their prime factors to determine their color category, and she asserted:

> Only when I have to do the algebra form. But if I'm doing color output, I don't have to, if my reasoning is based on the amount of prime factors.… All I have to know is if it's gonna be [an] even number of prime factors or an odd number of prime factors, or if they're going to be repeated prime factors. (February 28, 2007)

Naomi gave an example of this strategy for putting 50 in the yellow category. Because 50 equals 2 times 25, it has two 25s. From this factorization, she knew that she would have two of something. She explained that if a number has two of anything (i.e., a number with two identical factors), then it would automatically go into the yellow category. Naomi continued, "So if I know that fifty is two twenty-five[s], I don't have to break it down into two, five, five [$2 \times 5 \times 5$]. I don't have to keep going." Naomi also used this reasoning to explain why 42 would go into the red category. She explains, "Forty-two is gonna be three different prime numbers. I don't have to factor it out because I already know, odd number of prime factors." In other words because there are so few numbers between 1 and 50 (i.e., $30 = 2 \times 3 \times 5$ and $42 = 2 \times 3 \times 7$) with three distinct prime factors, Naomi had memorized those numbers and their color category. She did not need to factor them into prime factors.

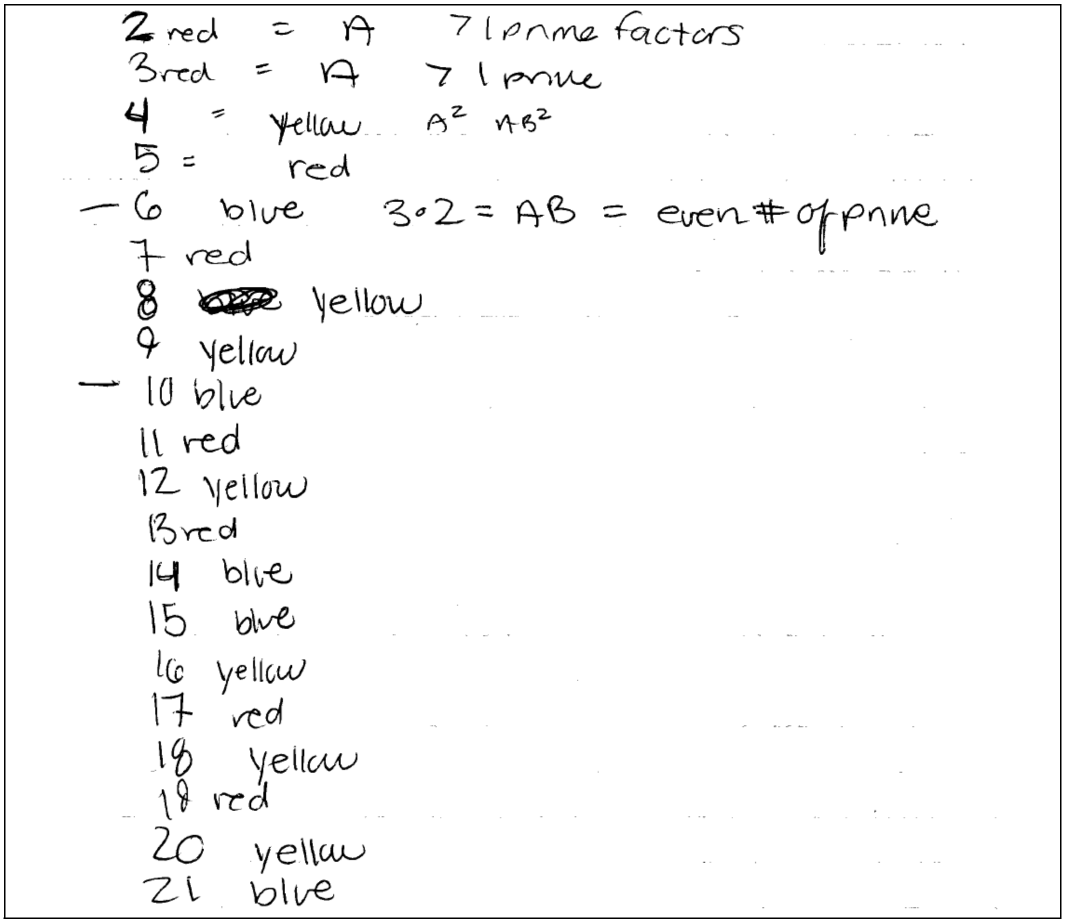


Figure 4.2. Naomi's color categorization of 2 to 21

Flexibility With Numbers

Naomi explained that she had increased number sense as a result of training with Flagway. *Number sense* referred to the ability to work with and understand numbers and their relationships, flexible mental computation, quantitative judgments, and how numbers were affected by mathematical operations (Greeno, 1991; Howden, 1989). I separated this theme into two categories: prime factorization of numbers and divisibility rules, and familiarity with small primes over large primes. Naomi was able to make several connections between natural numbers she was not sure she had been aware of before. Naomi spoke of connections she made

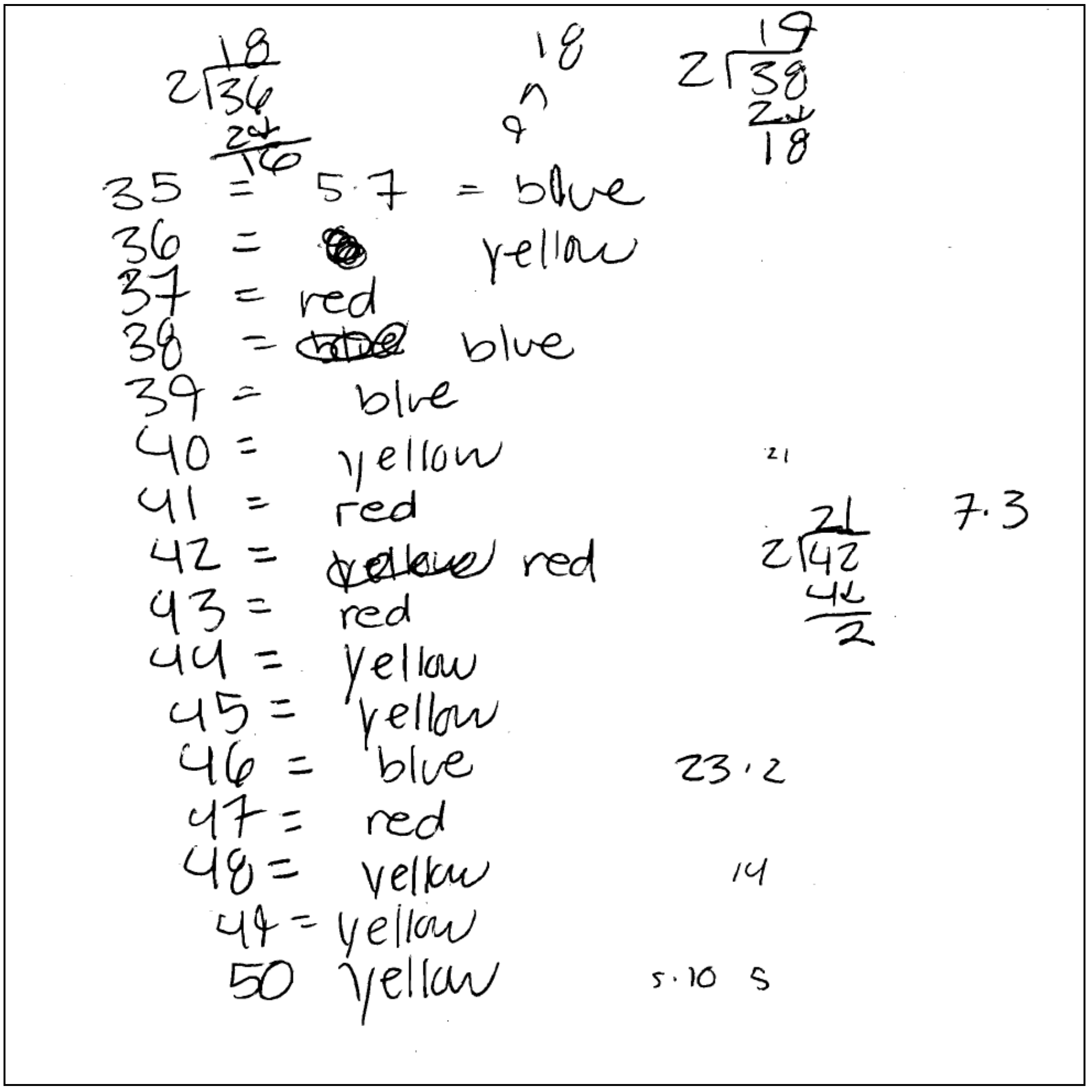


Figure 4.3. Naomi's color categorization of 35 to 50.

concerning how to factor numbers into prime factors and how she used divisibility rules learned in her early schooling to factor numbers.

Prime factorization. Naomi was able to explicitly articulate and demonstrate her understanding of the concept behind the Flagway Game. Through her continuous work with mathematics literacy workers and categorizing number activities in training, she realized qualities of numbers that she was not sure she had before. Naomi explained her understanding of the role of prime numbers in the Flagway Game:

> Two things that I found that I think I already knew but just never articulated it [are] that all these numbers are made up of primes. Like all of them are made up of, like, just prime numbers multiplied by each other, and they're done like differently or uniquely or things like that. So a lot of people, a lot of people know this but don't realize it when they're factoring. When we ask students, you know, "What do you notice about all these numbers?" A lot of people would be like, "Oh, well, these are all prime." Not really realizing that these are all prime, too, and these are all prime, too, and these are all prime too. So I think I had a moment where I was like, "Oh, of course, of course. Of course they're all prime because you can't break it down any further." Like the prime, the primes are the building blocks of all of these numbers. I am not sure if that is something that I knew from when I was a kid or something I learned when I was little, but that's like the main thing that connected this whole Flagway thing for me. That prime is so important not because, "Oh, all the primes go in red," but because prime numbers are making all of these numbers. And the way that the prime numbers make these numbers [determines] which color [category] it's gonna be. So the way the prime numbers are gonna make two, three, five, seven, eleven determines that those number are gonna be red. (February 28, 2007)

Using divisibility rules and familiarity with small primes over large primes. Naomi used divisibility rules she learned earlier in her schooling to help her become more familiar with numbers she was not use to analyzing for Flagway. For instance, Naomi used a rule that she learned to help her find the prime factorizations of numbers. When asked to factor 38 into its primes, she immediately associated the number 3 with 38 simply because 3 is one of its digits. She then checked to see if 3 was a factor. She explained that if you add the digits of 38, (i.e., 3 + 8 = 11), since 11 is not divisible by 3, it is not a factor of 38. Naomi searched for prime factors using this rule as one of her tests. This test helped her factor some numbers. Naomi also used this test because she was more familiar with some numbers than others. She explained that because she was familiar with the multiplication table only up to 12 times 12, it was difficult for her to factor numbers like 26 or 38 without doing the arithmetic on paper. As Naomi explained, she illustrated her work on paper (Figure 4.4). In her illustration, she tried to demonstrate by creating examples of two multiplication tables. She explained that in the 12 times 12 table, a number like 26 would not be there, but in the 12 times 13 table, the number 26 would be there.

Naomi referred to the prime numbers between 1 and 12 that she was familiar with as *low primes*. Prime numbers greater than 12 she identified as *high primes*. She explained:

> I had like a whole bunch of moments [during Flagway training].… One of them was not necessarily like now when I am thinking about numbers like thirty-eight, which is a combination of like a low prime and a high prime, two and nineteen….Thinking about numbers like twenty-six, I don't really know anything about that number, and I never really thought about the number twenty-six. I don't know what it's made of. I don't know, but then I found it's two times thirteen. And I think when I was little I never memorized my multiplication table…. It was hard for me, and like we'd take all these [tests] to try to memorize it.… So I think students who went to school that emphasized like where the multiplication table didn't go up to twelve, it went to thirteen, then they know about the number twenty-six 'cause it would be right there. But if you look at what I'm learning, my table goes up to twelve. Twenty-six isn't included. So I'm learning, I'm discovering like why I think about numbers in certain ways. So like when I was doing this process, I'm learning why I have to hesitate on thirty-eight. Because it's not three times something, it's two times something and I don't think two is repeated. So then I have to figure it out. I actually have to do it out. And then I realize, oh, it's two times nineteen. That's why I don't know anything about [what] this number is because I didn't know anything about the multiples of prime numbers. I didn't know anything about the multiples of thirteen. I don't know anything about the multiples of nineteen. Even eleven. Well, the multiples of eleven are easy, but nineteen. Anything like that. All the high prime numbers, I didn't know anything about the multiples of high prime numbers at all. (February 28, 2007)

Results of Flagway in Naomi's Understanding of Numbers

Naomi described one significant way her understanding of numbers was enhanced as a result of Flagway. She was able to communicate number concepts more efficiently. She explained:

> Like the knowledge that I've learned through YPP makes me seem like an amazing mathematician. But I mean that's just what happens when you go through the training and you learn about these numbers.…You are able to articulate things in a way that makes you seem like that. (February 28, 2007)

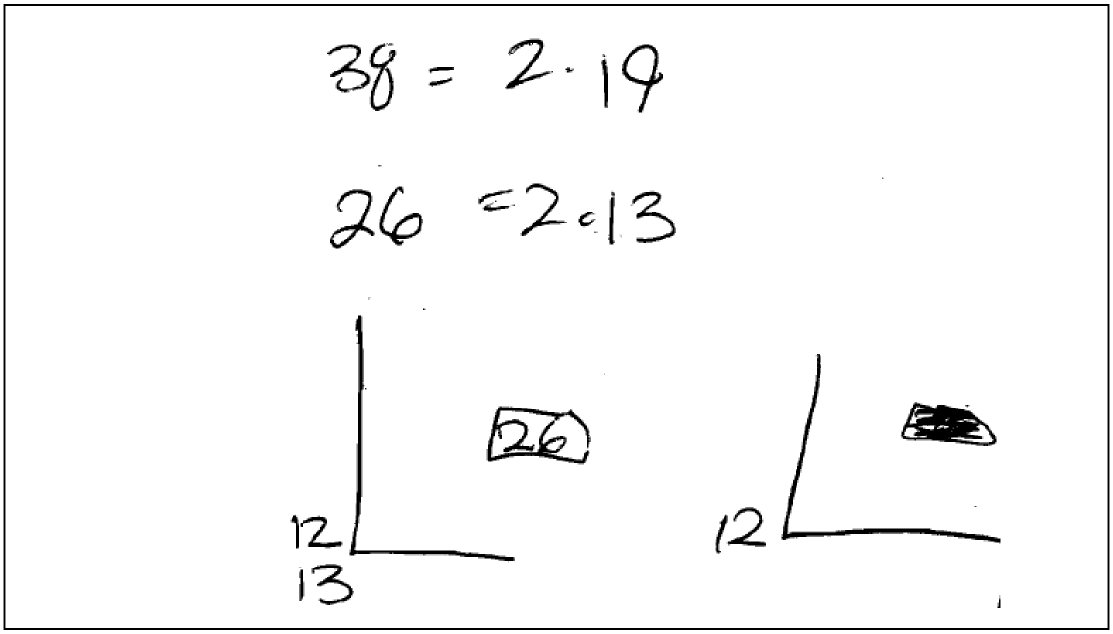


Figure 4.4. Naomi's illustration of the multiplication table with and without 12.

Summary of Naomi

Naomi, a CMLW, had several identities within the context of the Flagway training. She saw herself as a role model, an agent of change, and a confident doer of mathematics. Naomi demonstrated leadership skills in the training activities. She often challenged CMLWs and MLWs to think critically about number concepts they were required to know. Naomi believed that because she possessed strong improvisation skills and a good approach to the mathematical content of Flagway, the CMLWs and MLWs often thought that she knew more than she thought she did. Naomi's broader mission for herself was to improve the lives of others. She believed that one of her goals in YPP was to help MLWs become inspired to make changes in their respective communities. Naomi recognized the broader issues in education centered on mathematics literacy and students' lack thereof. She believed that by being a part of the process she could make an impact. Naomi was also intrinsically motivated to do mathematics. Although recognized the importance of minorities excelling in mathematics. She was afforded opportunities in school because of her strong mathematics skills.

Naomi also demonstrated an understanding of specific numbers in the Flagway Game. She employed two types of memorization strategies for 2 through 21 and for some of the numbers from 35 through 50. In the first strategy, she used color association to determine which of the color categories to place a number in. In the second strategy, she used the mathematical definitions of the color categories. She memorized the category of certain numbers that she was less familiar with to readily categorize them. Her memorization strategy was based on the factorization of the number.

Naomi explained that she had an increased flexibility with numbers as a result of Flagway training. She was better able to learn about and articulate some of the problems she had with her early number concepts. She explained that because of the work she did in Flagway, she had gained a clearer understanding of prime numbers and how each natural number is composed of a unique set of primes. Naomi made distinctions between small ("low") primes and large ("high") primes. She explained that as a result of her work with Flagway, she understood why she hesitated to work with numbers that were larger than 12. She had a very strong understanding of the multiplication table up to 12×12. She was less familiar with products of numbers 13 or larger. Naomi believed that the knowledge that she had gained from her work with Flagway had helped her appear to have strong mathematics skills. She attributed this appearance to the training and what she learned about numbers.

The Case of DeMarcus

Profile

When I first met DeMarcus, an African American male college mathematics literacy worker, I was immediately struck by his quiet, shy disposition, incredible politeness, and gentleness. Since attending New University, much of his time had been spent in student groups like his Greek fraternity. DeMarcus's desire to *do* mathematics shifted once he started high school. As he explained, when he went to high school his "love for mathematics … deteriorated." In both middle and high school, DeMarcus took several advanced mathematics courses. After attending high school, he felt he was surrounded by "people that were essentially math geniuses and people that were going to be doing that professionally" and concluded that mathematics was something not meant for him to do. A self-proclaimed perfectionist, DeMarcus also felt that he could not put himself in the "right frame of mind to do mathematics right." Once he entered college, DeMarcus decided to give up on mathematics altogether as a discipline of study because he did not believe he could do the work. In one of our interviews, he explained his view:

> I guess I would see other people and see what they were doing with math, and due to the fact that I didn't see myself capable of doing that, I was like, "all right, this clearly isn't for me." And so I kinda gave up on math in college. But at least I used to be good at it in high school. (February 20, 2007)

Although DeMarcus held this view of himself doing mathematics, he still recognized its importance. He also believed that a good grasp of mathematics and the confidence to engage in mathematics would probably make anyone "better off when it comes to solving problems." He stated, "I feel as though the skills that you get from doing math can translate to the skills that you utilize whenever you find yourself in a problem-solving situation, be it involving math or otherwise." The work that DeMarcus did in YPP also helped shape how he approached mathematics.

DeMarcus learned about YPP through a friend when he returned to Chicago from summer break in his hometown. DeMarcus attributed his motivation for becoming part of YPP to his desire to become a teacher and help urban youths:

> I think one part of it was that I wanted to build up my teaching experience. At first, I wanted to build up my teaching experience more than anything. And then when I got hired and then went through training for the first time, I heard the mission of the program. And then I experienced the challenge of the math the way that they were teaching it. And like 'cause I found the material a little difficult to grasp at first, so following that, I wanted the challenge. I felt as though, if they [MLWs] can get a grasp on this, I can get a grasp on this as well. And I wanted the challenge, or I challenged myself to get a grasp on this on the one hand. And on the other hand, I knew that they were there to work with inner city kids and improve their lives. So I considered…. so my incentive was the kids, but I wanted to take on this challenge in order to help the kids. (February 20, 2007)

DeMarcus's view and understanding of mathematics literacy was similar to his overall view of mathematics. He believed that mathematics literacy is "your ability to be familiar with math." He went on to explain:

> It is your ability to confidently be willing to engage in using math or problem-solving skills associated with doing math in order to overcome challenges. I think if one can be familiar with math and what it takes to be good at math, then they'll be one of those people that would be willing to take on something that a lot of people consider quite hard to do. And math is something, even I acknowledge, is something that's pretty hard to do. But in being willing to take it on, I think it's representative of your desire to take on certain other challenges. (February 20, 2007)

DeMarcus's interpretation of the YPP mission statement was centered on building both confident and competent students around him. He stated:

> I essentially feel as though the mission with the Young People's Project is essentially my mission in working with youth.… My goal in education is to empower.… I want to help build self-sufficient students. And I mean self-sufficient in that I want them to be of the character where they can go into a situation with as much confidence in their heart and success or failure to have the strength to take it on. And I feel as though with the Young People's Project they are doing something along the same lines. What I see as having the confidence to take on any challenge, success or failure, is what I kinda feel.… The YPP

> mission defines [it] as its full human potential. 'Cause I feel as though if you acknowledge your full human potential, then you won't fear anything that inhibits you from reaching that full human potential. And with YPP, it just so happens that they're doing it through work with math literacy when it comes to the lives of the high schoolers and elementary school kids. So maybe my specific mission in what I want to do with my life may not by default specifically state math literacy as being a way to accomplish it, but if math literacy is one of those ways of accomplishing it, then so be it. I'm more than willing to help, and I am more than willing to learn it in order to accomplish that goal. (February 20, 2007)

Identity

Role Model in Flagway Training

DeMarcus also had an identity of role model for mathematics literacy workers in Flagway training. Construction as a role model included DeMarcus exhibiting specific practices in training for other mathematics literary workers to emulate or look up to.

DeMarcus admitted that the mathematics in the Flagway Game was a bit of a challenge for him. However, he believed that by his "bringing his confidence to the table" and "willingness to learn this interesting way of doing math," students would feed off of his positive energy and engage in the mathematics on their own terms. DeMarcus also stated, "I'm the kind of person that tries to like lead by example." Referring to himself when talking about the MLWs, DeMarcus explained, "This guy, he can relate to me, and he is struggling with this as much as I am. But yet he is somehow finding a way to make this fun. So … let me see what I can do to achieve that same level of confidence and happiness to do it [the mathematics]." DeMarcus went on to clarify, "If [MLWs] can learn from that, if they can pick [the mathematics] up and implement [the mathematics] themselves, then I think the course will be set for them to strive for bigger and better things and even probably take [the mathematics] a step further than I would." DeMarcus also described his role as a supporter when referring to his relationship with the MLWs:

> I feel as though it is my role to be that confidence booster, that pusher in the right direction. I feel as though it is my role to build them up…. As I am learning more about people and different kinds of people, I want to build more of a learning setting that accommodates for these different personalities and accommodates for different learning styles.… It's my role to listen to these kids that I am working with, to pick up their personalities and their learning styles in order to best facilitate lessons built for them. So that essentially describes my role. To be that guide, that confidence booster, and that person that is constantly willing to learn from them so that they can learn from me. (February 21, 2007)

Because of DeMarcus's own struggles with mathematics, he often deferred to the MLWs when he spoke of the broader impact that he was working towards making in Flagway training and in YPP. Reflecting on some of the mathematics he learned, DeMarcus explained that he hoped his efforts in Flagway training helped MLWs to look at mathematics differently, and he wanted to encourage them to engage more openly in the mathematics. He explained:

> Just judging by the fact that [Flagway] reinvigorated my willingness to do math, I would hope that somehow [Flagway] would be able to reinvigorate their willingness to do math. Probably it's based on the level of learning that I, where I'm at right now. I love what it is that I'm doing. This is fun to me. So my influence in that respect would be to do the same thing for these kids. (February 28, 2007)

Agent of Change

DeMarcus saw himself as an agent of change when he described his past school experiences and his motivations for his work in YPP. He used the inadequacies he found in his schooling as fuel for his mission to make changes:

> I took a couple of economics courses here [at New University] that involved things like social justice and finding economic solutions to social inequalities. Combine that with a sociology course that I was taking at the time, and I found myself being drawn more and more and developing more and more of an interest in fighting for social justice and for striving for social equality, which is what eventually … led me to being an African American studies major. It was African American studies courses that also reinforced my belief in these social inequalities that I felt needed to be remedied. And from there, I'd sit here, and I'd take all of these history courses, and witness how education was essentially used as a tool against Black people for so long, what they didn't know was literally hurting them.… And all of a sudden, I felt the need to, and at the same time, I was experiencing difficulties at New that I felt were the result of my study skills and my educational background not being strong and toward the caliber of many of my peers. So

> I felt almost as though my education was somewhat of an injustice. To know that all … these peers of mine were apparently achieving higher than I was due to the fact that they were built on a better foundation. I won't even say better, that they were built on a different foundation than me.… So the combination for striving for social equality and improving the lives and the achievement potential for kids like me, those were the two of the biggest things that led me to be sold on trying to be an educator. (February 20, 2007)

DeMarcus's goal of becoming an educator was one way that he felt he could create social change. He went on to explain that after he graduated from New University, he was "leaning towards being a teacher with Chicago Public Schools."

DeMarcus also described the role he believed he had as a CMLW in YPP as a model of change. He viewed himself as the "change he wished to see" in the MLWs. In light of the "flaws" he recognized in his own education, DeMarcus was determined to come up with new and creative ways of teaching that would be more stimulating to MLWs:

> I'm willing to undergo or figure out any new way of instituting certain forms of education that will make these things more exciting, to build [the students'] confidence, and to have them more willing to take anything on that comes in their path. (February 21, 2007)

Increasingly Confident Doer of Mathematics

DeMarcus's possessed a comfort level in doing mathematics that developed overtime. In many respects, he was a more confident doer of mathematics as a result of his work with Flagway. An *increasingly confident doer of mathematics* is defined as an individual who demonstrated a sense of confidence or willingness to do mathematics that developed during the project.

DeMarcus attributed some of the challenges he had with mathematics to how he saw himself, his own perceived ability, or his enthusiasm. He also indicated that he had some apprehension about engaging in mathematics from prior schooling experiences because he perceived his peers to be better at the subject than he was. His desire to do mathematics evolved in a positive way the more he engaged in mathematics through Flagway. He realized that as a result of his work with Flagway, he had a renewed interest to do mathematics problems that he found challenging. DeMarcus was asked to find the prime factors of 2113. Through his reflection on this problem, he provided the following insight about himself in relation to doing the mathematics:

> I consider myself a person not too good at math. And I consider myself a person unwilling to do math for a large portion of my life. I feel as though in that respect, I can relate a lot to the kids that I work with.… Like [Flagway has] improved my willingness to do math in everyday situations. I can definitely say before this program, I'd see a number like twenty-one thirteen and refuse to touch it. And I felt as though, [if Flagway] was able to have this effect on me, then it would be possible for it, the kids that I work with, to have this effect [on them]. So, I guess one of the bigger influences on me is knowing this is possible. (February 28, 2007)

DeMarcus recognized that although his disposition to do mathematics had evolved, some of the young people he worked with still struggled with developing a desire to do mathematics. He identified that struggle as a problem he had with the young people he worked with:

> What's challenging for me is getting or convincing the kids to be willing to take their time in figuring out problems assigned or problems placed before them. 'Cause it's an issue that I had as well. Like I said, if you asked me a while ago, I would not be willing to try to figure out the factors of twenty-one thirteen, because I'd be of the stance where I don't have enough time for this. I am not going to even worry about this. Like, what's the point? And I would ask, "What's the point?" 'Cause I don't have a curiosity towards trying to figure out the factors…. I'd much rather just move on and like leave that in the hands of the next man. I feel as though with the kids that we are working with, they face similar problems. They're working with us, they see us doing these math problems and they're not so much willing to go about doing it. One, because they consider themselves not to be familiar enough with it. Like I didn't consider myself familiar enough with it. And two, they find themselves in a situation where if it's something that they are not going to solve immediately, then they're not gonna try to solve it.… With that said, I rationalize, I sympathize with them completely. Like I said, I feel as though it's something that we're raised to do as well. If it is something that we can't figure out in the allotted amount of time we are willing to put into it, then we are just going to give up on it. And I feel as though these kids are doing the exact same thing. So the difficulty comes in their [lack of] willingness to do something that they might not comprehend or gather in the quickest amount of time. (February 28, 2007)

Mathematics Strategies and Understanding of Number Concepts

Two major themes were revealed in DeMarcus's data: memorization for color association and flexibility with numbers.

Memorization for Color Association

DeMarcus used memorization as a strategy to determine the color outputs of the numbers 2 through 21. While doing the first mathematical task, DeMarcus immediately associated each number with a color and then wrote each number's prime factorization and its algebraic form. He explained that although the first thing that he wrote down was the color output, he had already done the calculation mentally. He explained that because he had done this process so long while training mathematics literacy workers over the previous months, he just knew which number corresponded to which color. The number 12 required some additional factoring on his part, so he completed a factor tree at the side of this paper. DeMarcus's work is depicted in Figure 4.5. DeMarcus explained the mental calculation that he did before writing the color output down:

> First…I broke down the prime factors, worked out the algebra form, and then I just wrote down the color. I think it's in part because I've been doing this for a while now that I just wrote down or did this in my head but wrote this down first. (February 28, 2007)

When asked to write the color output for 35 through 50, DeMarcus did not use memorization. He first decomposed each number into prime factors using factor trees, wrote down each number's algebra form, and then gave the color output. He explained, "I guess two through twenty or two through thirty.… Once you get beyond thirty, I'm definitely factoring the numbers first and then figuring out the algebra form and the color.… So thirty-five through fifty, I may be less familiar with so in this case I would do the factor tree system first" (Figure 4.6).

2	→	Red	2	A
3	→	Red	3	A
4	→	Yellow	2·2	A^2
5	→	Red	5	A
6	→	Blue	2.3	AB
7	→	Red	7	A
8	→	Yellow	2·2·2	A^3
9	→	Yellow	3·3	A^2
10	→	Blue	2·5	AB
11	→	Red	11	A
12	→	Yellow	2·2·3	A^2B
13	→	Red	13	A
14	→	Blue	2·7	AB
15	→	Blue	3.5	AB
16	→	Yellow	2·2·2·2	A^4
17	→	Red	17	A
18	→	Yellow	2·3·3	AB^2
19	→	Red	19	A
20	→	Yellow	2·2·5	A^2B
21	→	Blue	3·7	AB

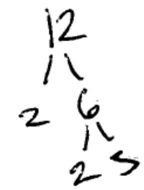


Figure 4.5. DeMarcus's color categorization of 2 to 21.

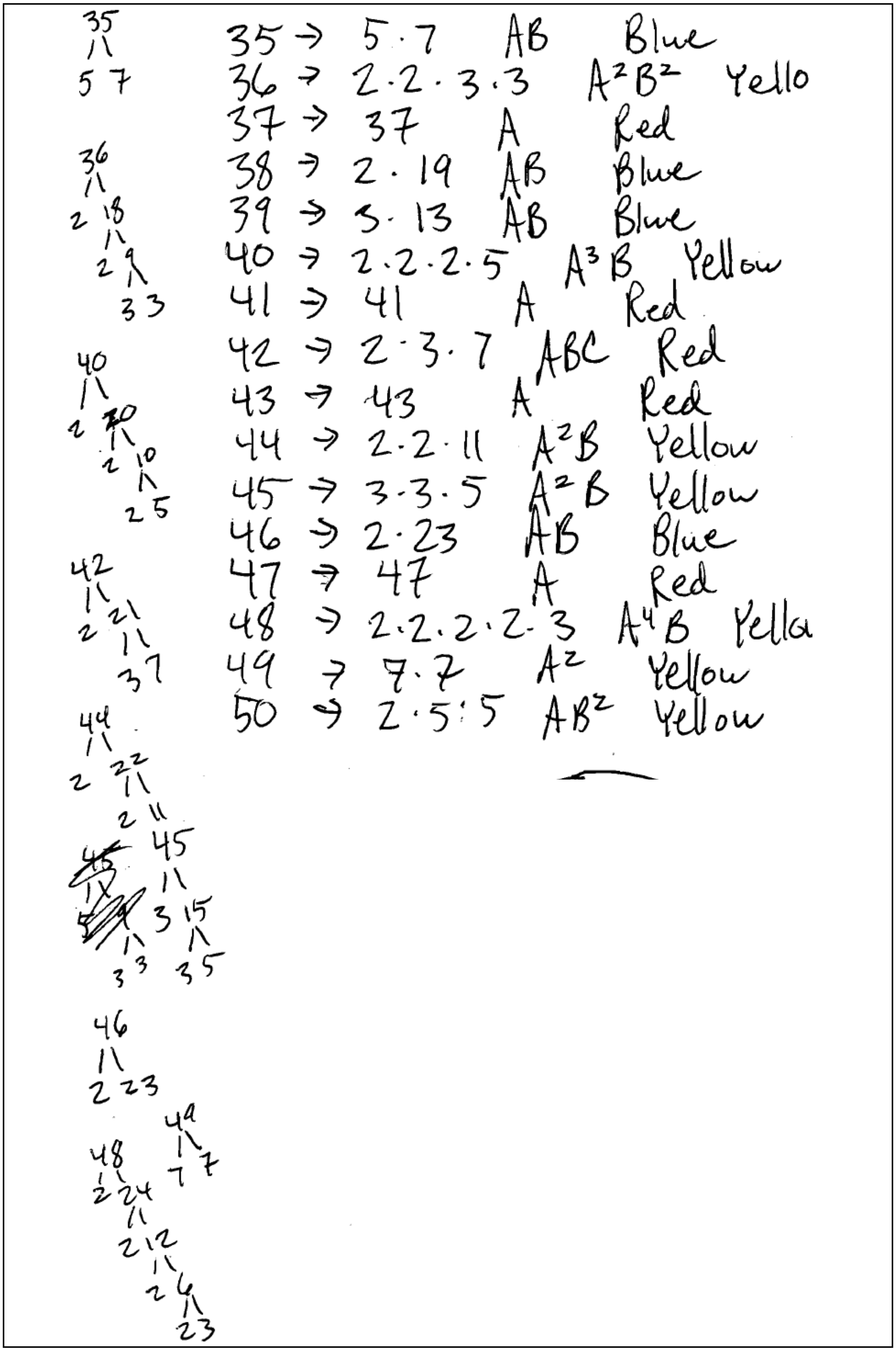
Flexibility With Numbers

DeMarcus provided many instances of increased flexibility with numbers that he said he had developed as a result of the Flagway training. This theme is separated into two categories: DeMarcus's prime factorization strategy and his use of divisibility rules and familiarity with small primes. Like Naomi, DeMarcus demonstrated connections he made between natural numbers. DeMarcus made connections related to how to factor numbers into primes and how he used divisibility rules to factor numbers.

DeMarcus's prime factorization strategy. DeMarcus used a prime factorization strategy that he said he developed from repeatedly working with the numbers during categorization exercises in the training. He explained that if he was trying to determine if a number were prime or if he was trying to find the prime factorization of a number that he was not familiar with, he would see if primes that he knew were factors of the number in question. He explained this reasoning using 41 as an example:

> For a number like forty-one.…Something that I picked up in doing this through practice, would be looking at the prime numbers like two, three, five, seven, eleven, thirteen, fifteen, and trying to see if those first few prime numbers up to fifteen, or I guess, let's see, fifteen, seventeen, twenty-three, like anything lower than twenty-three.…I would see if it goes into forty-one because I know twenty-three times two would be forty-six, and that's higher than what I need….I would just know that forty-one would of have to of been prime. It would have took me some time to...try to figure it out in my head, but I just knew that since any prime number up to twenty-three didn't go into forty-one, that forty-one was prime. (February 28, 2007)

DeMarcus then explained that "for a number like nineteen in multiplying that by two, I know I would get thirty-eight and that's too small." In other words, DeMarcus was looking at two consecutive primes 19 and 23. Because 2 times 19 is less than 41, and 2 times 23 is larger than 41, he is determining that 41 had to be prime because it cannot contain any other prime factors.



35 →	5 · 7	AB	Blue
36 →	2 · 2 · 3 · 3	A^2B^2	Yello
37 →	37	A	Red
38 →	2 · 19	AB	Blue
39 →	3 · 13	AB	Blue
40 →	2 · 2 · 2 · 5	A^3B	Yellow
41 →	41	A	Red
42 →	2 · 3 · 7	ABC	Red
43 →	43	A	Red
44 →	2 · 2 · 11	A^2B	Yellow
45 →	3 · 3 · 5	A^2B	Yellow
46 →	2 · 23	AB	Blue
47 →	47	A	Red
48 →	2 · 2 · 2 · 2 · 3	A^4B	Yella
49 →	7 · 7	A^2	Yellow
50 →	2 · 5 · 5	AB^2	Yellow

Figure 4.6. DeMarcus's color categorization of 35 to 50.

To confirm that his reasoning was understood, DeMarcus repeated his strategy for 43:

> For forty-three, I would know that forty-three was prime because again…twenty-three times two would be…forty-six, and nineteen times two would be thirty-eight. So both of those prime numbers are either too high or too low…for forty-three to be a multiple of them. So I would know that forty-three was prime. (February 28, 2007)

Using divisibility rules and the prime factorization of 2113. DeMarcus pointed out that because he had been exposed to the multiplication table growing up, he was completely confident with 2 through 12 and their products and factors. The numbers he had difficulty factoring were numbers 13 and larger. DeMarcus used the divisibility rules he learned early in his schooling to justify why numbers did not have certain small primes as factors. Like Naomi, DeMarcus defined *low primes* as primes that were less than 12. He also defined *high primes* as primes that were greater than 12 even though this was not a common terminology used in the training.

DeMarcus attempted to factor the number 2113 into primes. He first determined that 2113 was not an even number because it did not have 2 as a factor. Next, he added the digits of 2113 (i.e., 2 + 1 + 1 + 3 = 7). He determined that 2113 did not have a prime factor of 3 because 7 was not a multiple of 3. He also determined that 2113 did not have a prime factor of 5 because the number did not end in 5 or 0. DeMarcus continued using consecutive small primes but had some difficulty once the primes were greater than 11. He determined that he was not sure what the correct prime factorization of 2113 would be. He also explained that he needed more time to think about the problem. DeMarcus's initial work is provided in Figure 4.7.

Although DeMarcus had difficulty, he did not want to give up finding the prime factorization of 2113. He tried some alternative approaches with little success. After trying his prime factorization strategy, he then decided to consider 2114, which he said was "one number

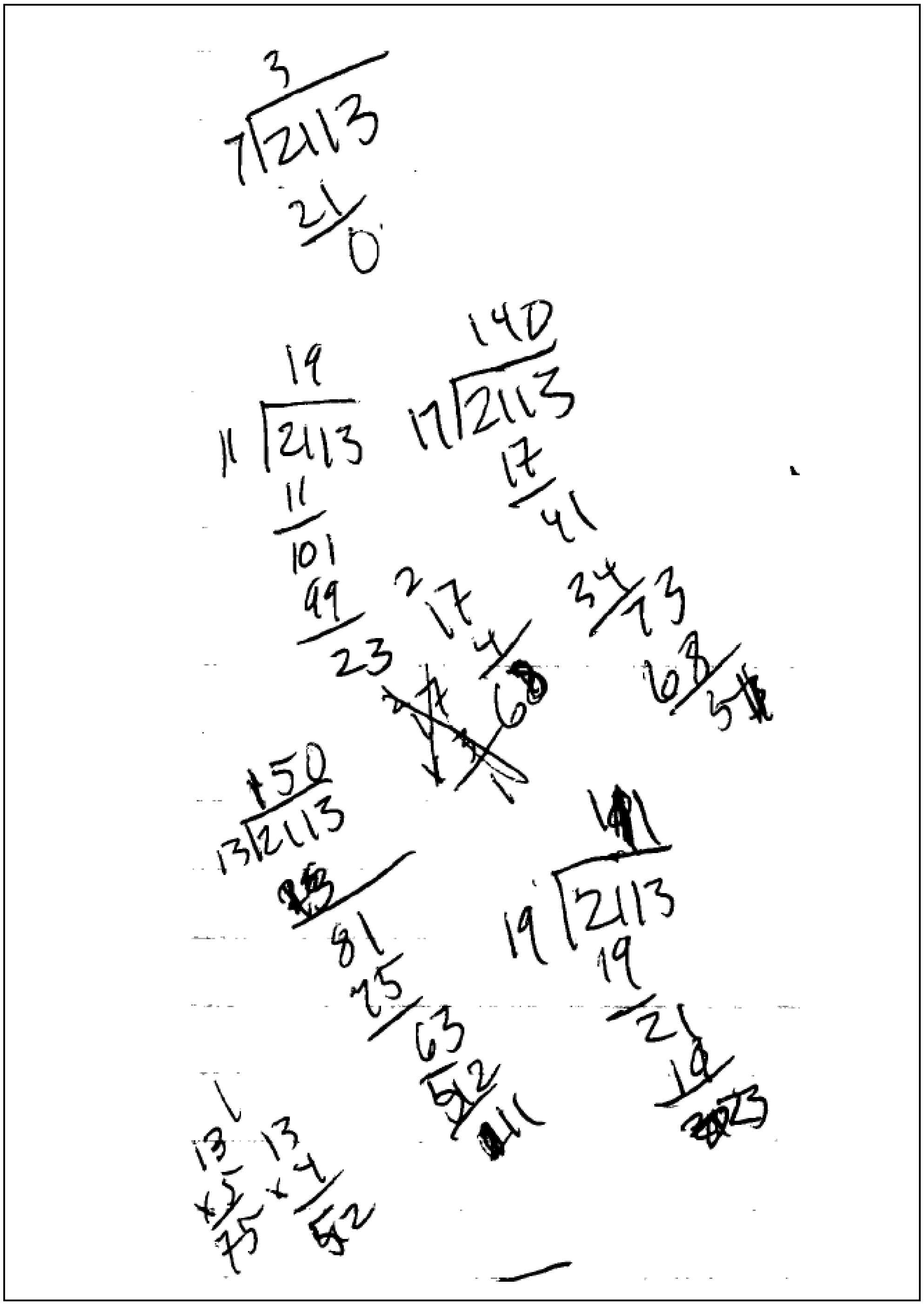


Figure 4.7. DeMarcus's work to determine the prime factorization of 2113.

up." He divided 2114 by two to see what factors were close to it. Since 2114 had factors of 2 and 1057, DeMarcus said that he would then see what the factors 1057 were. DeMarcus had little luck determining the prime factorization of 2113 by analyzing 2114. He then moved to the number 2115. He was asked how this reasoning was helping him to determine the prime factorization of 2113. He responded, “We’d at least be able to come close to a prime number that can possibly go into [twenty-one] thirteen.” Although DeMarcus did not complete the prime factorization of 2113, he determined from his analysis that “It must be some sort of a high prime number [that] goes into twenty-one thirteen.”

DeMarcus also made connections with his willingness and improved ability in finding the prime factorization of 2113 with the broader goals of the Algebra Project:

> When I initially heard about YPP … we were introduced to … literature written by Bob Moses or literature written about the goals of the Algebra Project. And something that … came up was the goal of … the Algebra Project … to be able to use numbers through association. And I feel as though that’s exactly what I am doing here. While I am not necessarily dividing by twenty-one thirteen, by all these numbers, I could be dividing by something close to it … so I can associate that with … figuring out the factors for twenty-one thirteen…. One of the things that the Algebra Project was working towards is being able to do math through association. Being able to draw those connections in math the same way that we do when it comes to reading, writing, and comprehending the English language. So essentially like we are learning math as though it’s a language. And its proven to be really effective for me. ‘Cause it’s got me, I would actually, like, once [in] a while I would probably get curious. For a number like twenty-one thirteen and try to figure out ways to factor it out. (February 28, 2007)

Results of Flagway in DeMarcus’s Understanding of Numbers

DeMarcus spoke of several ways that Flagway had influenced his understanding of numbers. One of the major impacts that Flagway had on DeMarcus was his overall approach to multiplication. In particular, the process of finding prime factors had helped him to look at multiplication differently:

> I would say the most significant impact [Flagway] had on me is my willingness to ask what numbers are multiples of thirteen? What multiples are numbers of seventeen? Like what numbers are multiples of numbers that I would have never remotely thought of multiplying before. I feel as though it expanded the possibility, the possibilities of how I do multiplication. (February 28, 2007)

DeMarcus demonstrated this impact by trying to figure out the factors of what he called "some very high number," 98. He first determined that since 98 is even, he knew that it was divisible by 2. He then said that 2 times 49 is 98. Since he knew that 49 is 7 times 7, that told him how to decompose 98 into prime factors (e.g., $98 = 2 \times 49 = 2 \times 7 \times 7$).

DeMarcus also described mathematics by association as a tool that had helped him to look at numbers differently. He stated,

> I definitely love this math by association….'Cause it makes figuring out different problems, different types of math problems, problems that I typically would refuse to do, I would be more willing to take a shot at it, or at least see what I can do to figure it out. (February 28, 2007)

DeMarcus explained that his work with Flagway had also strengthened his intellectual curiosity. It had helped him to "reacquaint" himself with his interest for mathematics and his "willingness to investigate mathematics." Through Flagway, he was ready to try to do mathematics just for fun or "just to have a better understanding of math" that he was confident of.

Summary of DeMarcus

DeMarcus, a CMLW, constructed identities as a role model, an agent of change, and an increasingly confident doer of mathematics, the context of the Flagway training. DeMarcus used himself as a exemplar to help motivate MLWs to do the mathematics in the Flagway training. He understood that the mathematics was challenging to him, but he wanted to lead by example and show mathematics literacy workers that they could grasp the concepts just like he did. DeMarcus also looked at himself as someone who could change teaching. Because of inadequacies he recognized in his schooling, he wanted to become an educator to make a difference in the educational experiences of youth. He also possessed a comfort level in doing mathematics that changed during his participation in Flagway. Because of his earlier schooling experiences in mathematics, he expressed some dislike for the subject. As a result of his work with Flagway, his willingness to engage in mathematics increased.

DeMarcus demonstrated specific understanding of numbers in the Flagway Game. He used a memorization strategy to determine which number was assigned to a respective color. Because he was familiar with the color categorizations of 2 through 21, he used memorization to assign numbers to colors. He used factor trees to help him think through the categorization of 35 through 50.

DeMarcus demonstrated increased number sense as a result of his work with Flagway. He explained a strategy that he utilized to find the prime factorization of a number. His strategy allowed him to determine whether a number is prime. It was also a way of finding the prime factors of numbers. He used divisibility rules that he had learned in school to help him find prime factors. He explained that the work done in Flagway training had influenced his approach to multiplication. He also indicated that he had a renewed sense of intellectual curiosity and confidence to do mathematics as a result of Flagway.

The Case of Charlene

Profile

Charlene, an African American female high school mathematics literacy worker, was typically quiet, with a solemn look on her face. She was not as talkative as some of the other MLWs and often maintained a quiet manner at the beginning of training sessions. Charlene was very active in school activities, like helping her peers with their schoolwork and drama. Upon arriving at a training session, she usually had a lot on her mind and had to unwind first before interacting with others. Once she was comfortable, she offered an occasional smile that could brighten up the room. Not only was Charlene an MLW in YPP, she was also rehearsing for a play that opened a month later at school.

Charlene described herself as sweet and cheerful. She also explained that she enjoyed helping her peers any way possible. I wanted to know what her career aspirations were since she enjoyed doing mathematics and working with others. She pointed out that although she was strongly considering becoming a mathematics teacher, she was currently interested in pursuing a therapy-related career but did not have all the details figured out. In addition to helping her peers, she also enjoyed working with young people on mathematics, exposing them to different approaches.

Charlene explained that she had always enjoyed doing mathematics. She often tried to encourage others to take a similar perspective. She commented about her feelings towards the subject:

> It's fun, and I would view it as being the best subject ever because it's fun to learn new things…. It's exciting when you're, like, "Oh, I didn't know you can do it that way." And then it's like so many other ways you can get around a problem and figure out how to do it and then it becomes interesting. At the same time it becomes fun. (February 20, 2007)

Charlene learned about YPP from her mathematics teacher and some of her friends. Several of her friends had participated in YPP during the summer and told her about their positive experiences when they returned to Abelin in the fall. They told her about how they played mathematics games with children with the goal of showing them "how to do math and think about math in a different way." As Charlene stated, "I thought that it would be a good thing to do for the fact that I like to teach people, help people, and at the same time I like math." As a result, Charlene decided to join the program that fall to see if she would enjoy it. Because of her positive experience with YPP in the fall, she decided to return in the spring. Charlene explained her reason for returning:

> Well, the first time, it was really fun. ‘Cause it was exciting knowing we had the chance to go to another school, teach the elementary kids.… Although it was a little frustrating, but at the same time, it was kind of fun being able to sit down and teach little kids to think about numbers in a different way. So I wanted to do it again because I like to teach, and that’s why I wanted to be in the outreach sites so that I can go over and teach the kids. (February 20, 2007)

When Charlene was asked why working with the elementary kids was a little frustrating, she explained that the children she worked with were very “active.” Often, it was challenging to find a way to get their attention and to keep them all on task.

I had several conversations with Charlene about the impetus for her work with elementary school students implementing the Flagway Game. She spoke of negative comments she experienced from some of her peers. Some of her peers did not understand her motivation for going to outreach sites or doing this kind of work altogether. Some of Charlene’s peers did not understand why she would want to spend so much of her free time outside of school going to elementary schools to teach mathematics and play mathematics games. Charlene explained that it did not matter what opinions they had about what she was doing: “You have to take a stand and do what you think is right,” and “you also have to make a difference.” She saw that as an important lesson she learned from her parents and from her upbringing in the church.

Charlene viewed having mathematics literacy as possessing a multitude of understandings:

> Well, I basically describe it as understanding the basics and understanding what math really is. Like really knowing what it is and not just thinking about it as it being boring or thinking about it as being just adding, subtraction, multiplying. Math can also be fun. So, when I think about math literacy, I just basically think about understanding math in a different way and not in just one way, because math can be explained in many different ways. (February 20, 2007)

As far as the YPP mission statement was concerned, Charlene saw the mission as being part of a community and the development of leadership. She also viewed the mission as helping people understand and like mathematics beyond basic operations like addition and subtraction:

> Well, I think it means like as being part of a community, as being a person inside of your community. It's like, they want us as the students to participate in the YPP program to become a leader in their community, to help build and help encourage the younger people or whoever around you to understand math. Like just to like help them to think about math in a different way, not just all … add and subtraction and that nature or whatever. It's like to make it more fun because there's a lot of people who hate to do math, who hate to count and everything because they think it's so difficult. So I think the YPP program is basically trying to have people to think about it as a fun way, not to hate it, to actually like it. And to understand it, so when you do get older you won't have to struggle with it and you can like do whatever you want on your own. So, it's basically just trying to help your community to become better at math. (February 20, 2007)

In regard to the broader goal of YPP and its impact on urban youth, Charlene stated:

> Well, I would say YPP is important… I believe that as a whole … mathematics is the most complicated thing for people within the community. And it's like more people struggle with math…. YPP is here to help you want to learn about math and to become excited and to understand math. I think it is important cause [YPP] wants you to understand that math is something you need. And if you need it, why not make the best of it and make it fun at the same time. (March 1, 2007)

Identity

One Who Perseveres

Charlene's construction as one who preserves and is committed to mathematics literacy work was exemplified through the experiences she communicated about with the elementary children she worked with when implementing the Flagway Game and her overall commitment to the work. *One who perseveres* is defined as someone who continued to persist in or remain constant to a purpose, idea, or task in the face of obstacles or discouragement within mathematics literacy work.

Charlene realized that no matter how disruptive the children she worked with became, she had to move beyond her frustration with their behavior, not give up, and figure out how to reach them. She explained that she was firm with students but still had to find a way to help them do their work:

> I went to a very difficult [YPP elementary] school.… It was really … young kids, and they wanted to be active, and they just didn't want to sit in one place all the time. There was a handful who didn't know [Flagway], and there was like a couple who knew it. And it was like, How am I gonna get everybody else to understand it? (February 20, 2007)

Charlene's initial frustration helped her to think broadly about her practice. Instead of focusing just on their behavior, she realized that she had to find different ways of engaging the students.

Charlene also commented on an outreach experience that she had at an elementary school with a young girl. As Charlene recalled, when asked, the young girl did not know or understand any of the concepts that the CMLWs and MLWs were teaching about numbers. "She just wanted to sit there; … she could never understand the basics of those numbers going in a color." Charlene further explained, "But every day, she would just like hang on to me. She would always just hold my arm, hold my hand. She would always want to be under me." Charlene admitted that while she wanted the young girl to do the work, she did not want to hurt the girl's feelings by pushing her away. At some point, Charlene made a decision to "get hard on her." She further explained "I'm [going to] let her be under me, but at the same time I have to teach her, too. I gotta teach her and I can't just let her have her way all the time." Charlene's sternness paid off in the end. The young girl finally understood the content. Charlene remembered, "And when I finally [saw] her get up and do the Flagway thing, I was like so excited. Like, wow, she actually got up and did it."

Charlene also saw benefits from her perseverance when she was recognized at the end of the fall semester for her work in YPP:

> I was really playful. But I always stayed on my work…. I always stayed on my work.… Like at the end of the program,… I actually got a reward. Me and my friend. I actually got a reward because they felt that we [were] the main two students who stayed on it [and] who did whatever we had to do. It was like, yeah, I played around, but when it was time to work, I did it. I got it done. But I didn't play around all the time. So, it was like, I was like amazed they actually gave us the reward for being the two best MLWs for that session. (February 20, 2007)

She continue:

> And then like this session, … I come in mad, but I try to put it aside. But it is like sometimes it gets the best of me. But I still try to concentrate … still focus on what I need to do, what I have to do. Because I joined this program to help others and to help others understand math. So it's like I have to put aside my feelings, put aside how I feel that day. Or whatever is going on with me.… So this session, it's like I'm ready to do work. (February 20, 2007)

These experiences of working with elementary school children have helped Charlene persist. In addition to these experiences, Charlene believed that because she was recognized for the work that she did in YPP, that helped to deepen her commitment to the work and grow as an MLW.

Agent of Change

Charlene also saw herself as an agent of change when she described her role as creating an enjoyable experience for others when doing mathematics. She believed that it was important that she help others to view mathematics as entertaining. Charlene illustrated this view when she spoke about her role with students:

> When you see [the children], … when you first bring [Flagway] to them, like they don't understand it. And it's like they don't want to know. But once I sat down with them and made it fun, it's like they understood it. And then every time I would come back, they would be so excited to play again.… So it's like, I see myself, it's like helping them to make it fun because I love math, and I don't want anyone to hate math.… So I see myself as trying to help build their knowledge and help also make it fun because a lot of young kids don't want to do anything that is not fun. So it's like, I see myself as basically helping them to understand it and at the same time enjoy [themselves] in doing it. (February 20, 2007)

Charlene reiterated this notion when she described her role in YPP:

> Basically [my role is] to help the little kids to understand [mathematics]. To know what it is, to know what it means. To have math literacy and to basically understand the process of how to do math, … how to get from one point to the other. And actually enjoying yourself. It's all about enjoying yourself. Because if you don't enjoy yourself at doing something, you're not going to do it right. And just basically I want them to have fun with it. Don't hate it. So my overall thing is to help them to understand and to think about math and don't just like put it to the side. (February 20, 2007)

Confident Doer of Mathematics

Charlene said that mathematics had always been fun for her and also expressed a strong willingness to always engage in it. She recognized the challenges of learning mathematics and admitted that it can be frustrating at times, but chose to push herself and do it anyway. Charlene reiterated this point by saying, "Math has always been fun for me, because I love it so much. It's not that it's easy, it's just like it's fun. And like when I do it, it becomes easy because *I make it fun*. Being a sophomore it's getting a little hard, but at the same time I try to make [it] fun because I love math."

Mathematics Strategies and Understanding of Number Concepts

Three major themes were revealed in Charlene's data: memorization and her number and color association, her definition of a prime number, and her quickness with numbers.

Memorization and Charlene's Number and Color Association

Charlene used memorization to remember the categories for 2 through 11. She placed 2, 3, 5, 7, and 11 in the red category. She placed 4, 8, and 9, in the yellow category and 6 and 10 in the blue category. This was not surprising since mathematics literacy workers often worked on categorizing the numbers 2 through 11 during training. When Charlene was asked to categorize numbers greater than 11, she did so with relative success. She placed eight of the numbers greater than 11 in their appropriate color categories, but two of them in the wrong category. She placed the 18 and 20 in the blue category when they belonged in the yellow category. Charlene explained her decision for placing the numbers:

> Well, for the red, I used all prime numbers. And its algebraic form is only one term, which will be like … for example, two. If you break that down, it's already prime. So [the] only numbers that will equal two [are] one and two (see Figure 4.8). So in algebraic form, that would just be the letter *A*. And for the yellow one, all of these are composite, … for example, four. When I break four down, it's two, times two and [its] algebraic form, it's one term squared to any power. So that's why in yellow it's only … numbers that have a power. And for the numbers in blue, … they all have two algebraic letters. For example, six, if you break it down it would be two and three. And the algebraic form [of] that would be *A* times *B*. (March 1, 2007)

Charlene explained how she placed numbers greater than 11 into their appropriate color categories. Because of the numbers she wrote down in each category, I decided to ask her if the numbers she placed in her blue category satisfied the definition she provided me (see Figure 4.9):

> I: All of the numbers in blue that you've put there have an algebraic form of *A* times *B*?
> C: Yeah… It has two or more.
> I: What do you mean "two or more?"
> C: Wait. Hold on. Hold on. Well, for blue…they all have like one term, it can be to any power, but it's all, it's two terms. Like *A* and *B*. It could be A^2 times *B* or it could just be *A* times *B*. But for the yellow, they're only one term to a power. So what makes yellow and blue different is that [they both have] a power and a term, but [blue] also has a second term.

Charlene further clarified that "for yellow, all numbers have one term to any power. Meaning it could be one term in A^2 or as in A^3. So it can be to any power. And for blue, it's more than one [term] in their algebraic form." She was then asked to write down her definition of what goes into to each color category. It appears that Charlene memorized the algebraic forms for simple numbers like 2 through 11 (e.g., A, A^2, A^3, and $A \times B$, respectively) and the categories that they corresponded to. When the numbers and their algebraic forms became a bit more complex (e.g., $A^2 \times B$, $A^3 \times B$, $A \times B^2$, $(A \times B)^2$), she had a more difficult time figuring out where the numbers went (Figure 4.9). Using her definition, she wrote the numbers 2 to 21 in the color categories shown in Figure 4.10.

Charlene had a difficult time providing an explanation for her work. She had developed her own theory about why the numbers should be in each color category. Beyond the algebraic

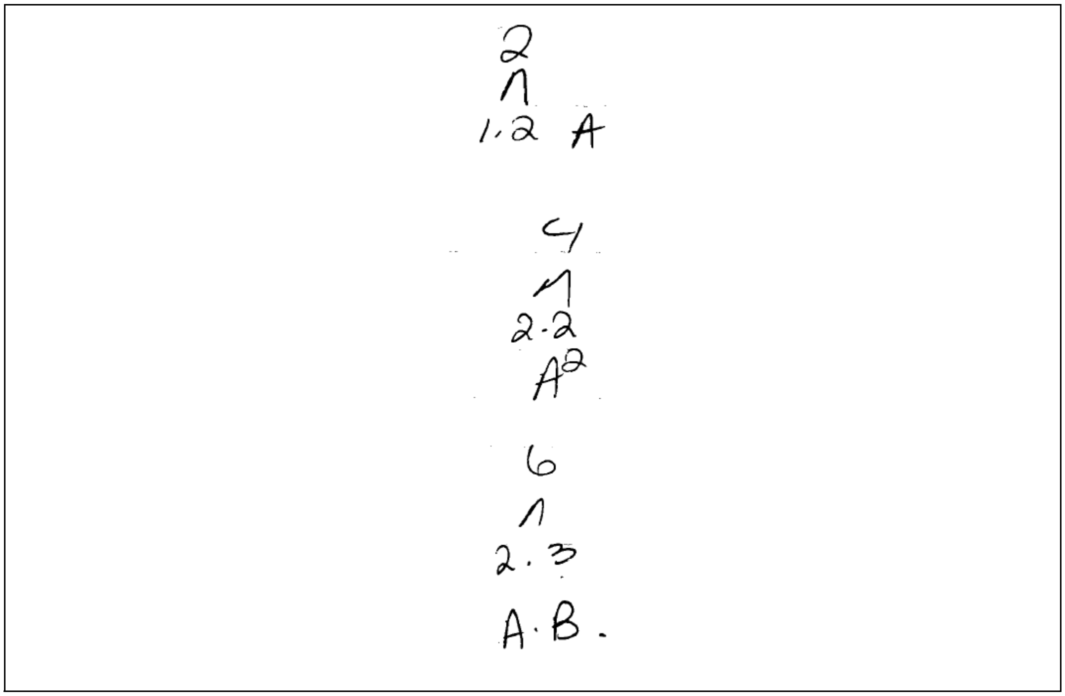
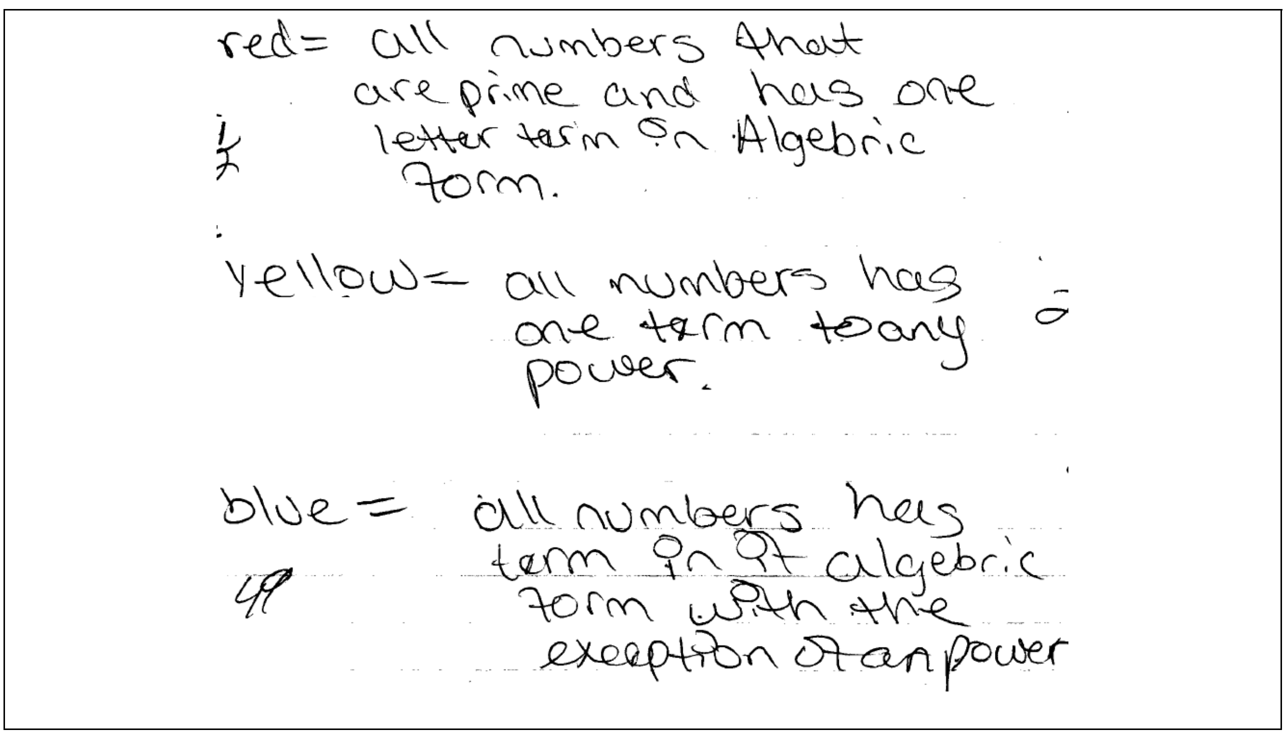


Figure 4.8. Charlene's explanation of 2, 4, and 6, their factorization, and their algebraic form.

forms she provided for 2, 4, and 6, her theory did not hold up for larger numbers. For Charlene's theory, all prime numbers went into the red category, all prime numbers raised to a power went in the yellow category, and the product of two or more different prime numbers went into the blue category. Charlene's theory was further demonstrated when she had to categorize the numbers 35 to 50. Using her definitions for each color category, Charlene was able to correctly decompose most numbers into their prime factors and show their algebraic form. But using her definition, she found that she only had one number in the yellow category, which was a problem for her at first. As she decomposed each number, she quietly asked herself "Why aren't there any yellow?" She initially saw this as a problem then quickly dismissed it. She incorrectly placed the numbers 36, 40, 44, 45, 48, and 50 into the blue category when they belonged in the yellow category. She also placed the number 42 in the blue category when it belonged in the red category. Even in some of Charlene's work (Figure 4.12), she incorrectly labeled, 39 with an algebraic form of *A,* and 36 with an algebraic form of A^2B. Charlene's categorization is depicted in Figure 4.11, and the rest of her work is depicted in Figure 4.12. I later asked Charlene why she thought there was only one number in the yellow category. She offered the following as an explanation:

> I'm not sure. I know from my definitions I know forty-nine fits because broken down, prime factors are seven and seven, which in algebraic form would be A^2. But it doesn't seem like any other numbers are the same way… That's the reason why I didn't put them with yellow, because its algebraic form isn't one term raised to a power. (March 1, 2007)

Although Charlene worked to develop her own theory for the number categorization, she had gaps in how she defined what went into each category and her theory was wrong.


red= all numbers that are prime and has one letter term in Algebric form.

yellow= all numbers has one term to any power.

blue= all numbers has term in it algebric form with the exception of an power

Figure 4.9. Charlene's definition of the color categories in the Flagway Game.

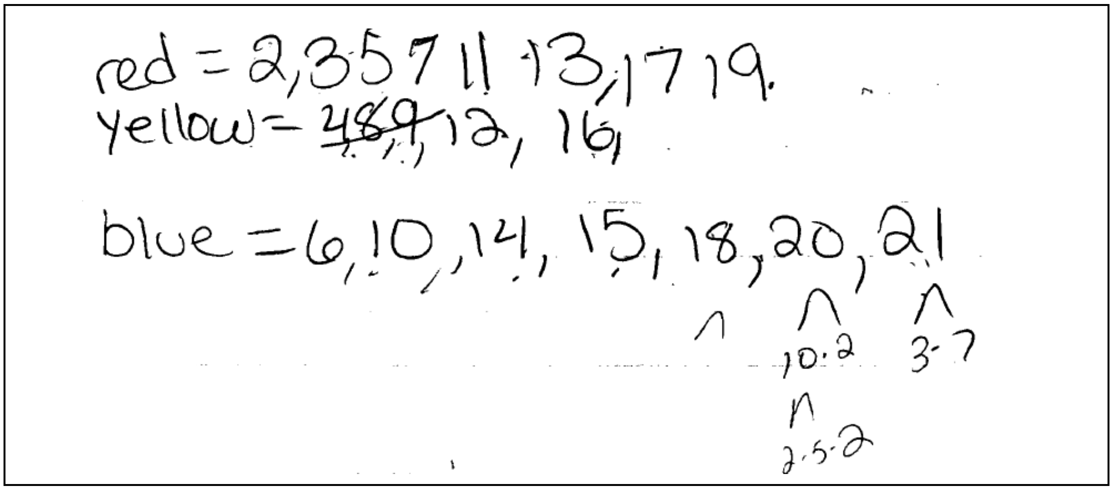


Figure 4.10. Charlene’s color categorization of 2 to 21.

Charlene’s Definition of a Prime Number

Charlene was able to identify prime numbers but had difficulty articulating clearly the definition. She offered various attempts to define a prime. The following dialogue provides her explanation:

> I: So how would you define a prime?
> C: Okay, well, I always thought that a prime number is a number that, a number being multiplied by another number to get a prime, wait…
> I: So hold on, take a minute. Take a minute. Think about it. I want you to write it down. I think that would be better. Just write it down rather than trying to speak it. Write it.
> C: My definition for a prime number is a number that can only be multiplied by itself and one to equal that number.

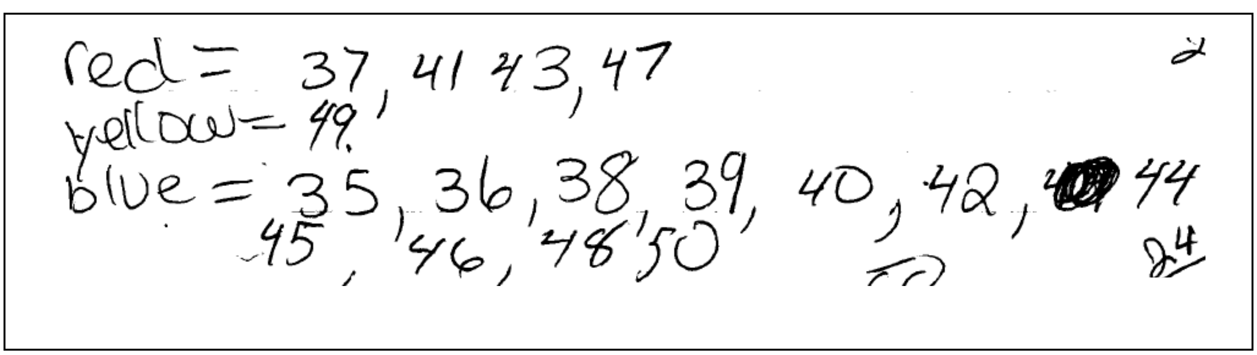


Figure 4.11. Charlene’s color categorization of 35 to 50.

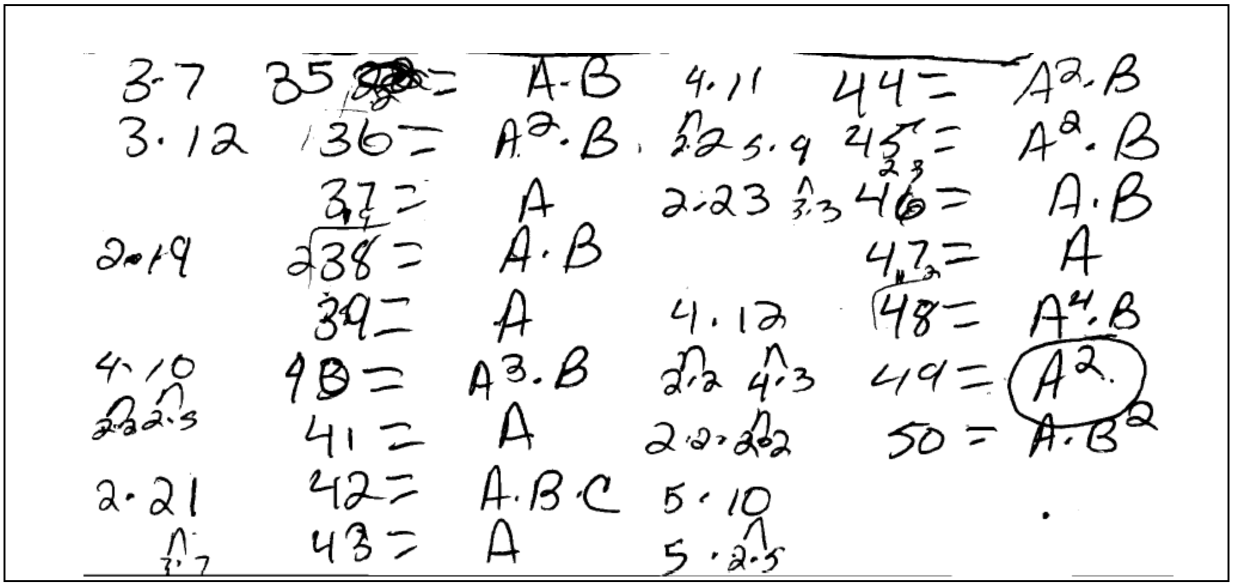


Figure 4.12. Charlene's factorization of 35 to 50 with the algebraic form.

> I: So give me an example of that definition.
> C: Well, for example, two. Two is a number that can only be multiplied by two, which is itself, and one to equal two.
> I: And that's why two would be prime?
> C: Hmm mmm.

Charlene also wrote down her definition of a prime number (Figure 4.13). I was then asked her to give an example of a number that was not prime and explain why it did not fit her definition. For that explanation, she used 4. She explained:

> For example, four. Four is a [composite] number because [by] looking [at my] definition, which is a number that can only be multiplied by itself and one to equal that number,…If I plug in four as saying four can only be multiplied by four and one to equal that number. Which is true. But, those are not prime. Those are not its prime factors. Its prime factors are two and two. So I would like to restate my definition as saying a number that can only be multiplied by itself and one [and] equals that number and only have two prime factors. Wait. Because if I plug in four in this definition, it sounds true because, actually no, a number that can only be multiplied by itself and one equals that number. You can also multiply two by two to get four. So therefore my definition is correct. For the fact that I put *only*. So two can only be multiplied by two and one to equal two. There's no other number that can be multiplied by two or by one to equal two except for two and one. (March 1, 2007)

In her explanation of 4 not satisfying the definition of a prime, Charlene restates her definition and offers that a prime number only has two factors that when multiplied will give you that number, itself and 1.

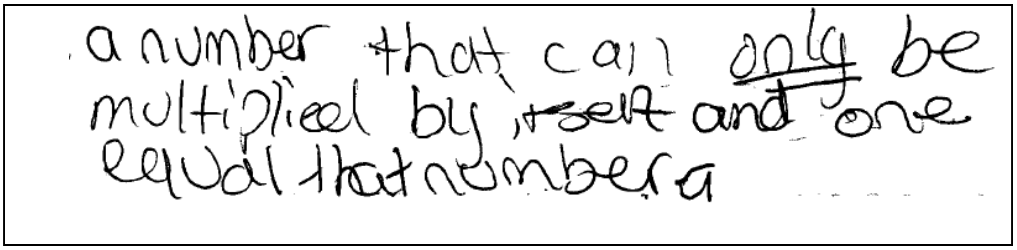


Figure 4.13. Charlene's definition of a prime number.

Flexibility With Numbers

Quickness with numbers. One of Charlene's goals was to be able to find the prime factors of numbers quickly. Charlene explained that as a result of doing the categorization activities for the Flagway Game, it has helped her to be quick at decomposing numbers:

> Actually [Flagway is] teaching me a faster way … to hurry. Like really think of a number and find out what its prime factors [are]. So it's actually helping me to think quick when it comes to giving a number and how to break it down in algebraic form and also breaking it down to a prime number [factorization]. (March 1, 2007)

Charlene also clarified that the mathematics activities in Flagway helped her to think what to do with the numbers and how to solve problems. She associated quickness with numbers as a skill she could use in her mathematics classes. She also cited a real-life work context where quickness with numbers is an invaluable skill:

> Most of the time in math class we usually have competitions, and we got like boys versus girls or one team versus another team.… You have to be quick, and you have to think fast in order [for] you to know [and] actually understand how to get the problem. I used to work at a candy store. And at a candy store you have to know how to count. You can't be sitting there like, "Oh, what's one plus one? How much change do they get back?" So it's like you have to think fast and understand.… Once you're given a problem, you have to know how to work it out and get it much quicker because the customers are gonna get really angry at you if you [are] sitting there counting [on] your fingers like, "How much change do you get back?" (March 1, 2007)

Charlene's Attitude and Working with Others

Charlene explained that because she may pursue a career in teaching, the experience of working with Flagway and with children was helping her to prepare for the future in many ways. She indicated that the most effective way Flagway had helped her was with her attitude:

> Most of the time when I'm mad, I don't feel like doing the work.… I'm trying to you know, become better at my attitude, and most of the time, some of the things we have to do is not fun to me. And when it's not fun, it's like I don't want to do it. So [I'm] basically learning how to have a better attitude. (March 1, 2007)

Charlene later acknowledged a shift in her attitude in a personal reflection about her work at Abelin:

> This working experience and environment it [have] changed me to a better person, such as my attitude. My attitude has changed a lot. I have learned how to control it while being in a working environment. (Personal reflection)

Charlene also explained that the team effort of the mathematics literacy work was teaching her how to rely on others when she had difficulty working with the elementary children:

> Going out to the outreach sites is like you're a teacher. You're teaching these students.… Now you may get frustrated. You may not know what is the best way to teach the children.… Or how to get them to understand [Flagway]. So it's teaching us to learn how to go to others, get help from others and [learn] how to accept their help.… And also for others to learn how to give help. So you know maybe what you're doing isn't good enough to get the students to understand.… Maybe your teammate [has] a better idea, or maybe your teammate can explain it in a different way. So it's all about helping each other out and working as a team. (March 1, 2007)

Charlene stated that the success of the work with Flagway occurred because it was done by young people. Young people provide a different approach to teaching mathematics than an adult would provide.

> As far as us as youth going out to the outreach site, it [makes] it more fun because you don't really like to be set in one place and adults just … lecturing to you.… And most of the time, when you are working with someone you know in your age range, it's more fun, and like we could relate to each other more. So I think that's the best part about … wanting us to think about math in a better way because we have younger people doing it. (March 1, 2007)

Summary of Charlene

Charlene, a MLW, constructed identities as a one who perseveres, an agent of change, and a confident doer of mathematics in the context of the Flagway training. She found it challenging to teach the elementary school children the Flagway Game because of their lack of focus. But she never gave up. She understood that she had to figure out different ways to reach them. Charlene was also committed to mathematics literacy work. She admitted that there were days during training when she did not want to participate. But she often drew on her broader mission for doing mathematics literacy work and the personal commitment she had made to help the children. This mission and commitment helped sustain her and also helped her to maintain focus on the work. Charlene also looked at her role in YPP as being an agent of change. In this sense, her main priority was to help others have an enjoyable experience when doing mathematics. Because of Charlene's love for mathematics and the positive energy she brought to it, she believed that she could be instrumental in changing the way others viewed the discipline by bringing fun and excitement. Finally, she was intrinsically motivated to do mathematics. She always enjoyed doing mathematics herself, and she reiterated that even when she found mathematics challenging, she tried to make it fun.

Charlene demonstrated some understanding of numbers in the Flagway Game. She used memorization to remember how to categorize 2 through 11. Because the understanding she had of the Flagway categorization, she developed her own incorrect definition, for number and color association for each category and made errors. She had some difficulty providing an explanation for the color categories she developed. Charlene could recognize prime numbers when they were given to her, but she had some difficulty articulating a definition.

Charlene also indicated that as a result of Flagway, she had developed quickness in decomposing numbers. She viewed this as a skill she could use in mathematics classes and in a work environment where having quick number proficiency is important.

Charlene had also seen a shift in her attitude as a result of her work with Flagway. Even when she did not find the work that she was doing in training exciting, she was learning to maintain a positive disposition. Charlene also indicated that she is learning to work with others. That is, she was learning how to rely on other mathematics literacy workers and use them as a resource when she had difficulty giving explanations to the elementary students.

The Case of Phil

Profile

Phil, an African American male high school mathematics literacy worker, was soft-spoken and had a large frame. In addition to participating in YPP as an extra-curricular activity, Phil was also active in journalism at Abelin. He described himself as an outgoing person who liked to speak up in class. He declared that he was "not a shy person" and often liked to joke around.

Phil described mathematics as "a great thing to learn." He recognized that the difficulty of the content area he was working on might affect whether he liked mathematics or not. During the time of the study, Phil was enrolled in Geometry and was having difficulty with some of the concepts. He pointed out that he was good at algebra even though he got problems wrong from time to time. Overall, he thought that it is beneficial to learn mathematics. Phil stated, "[Mathematics is] getting you ready [for] what you gotta expect … in your future." He went on to say, "It makes it good for me to learn, [because it's getting] me ready for test prep.… The world is based on math and science." Phil believed that mathematics is all around us, in places like a “grocery store or a gas station.” He proclaimed, “[In] any store that you go to, you will see mathematics.”

Phil had learned about YPP from one of his mathematics teachers. During his freshmen year at Abelin, his mathematics teacher noticed that he often sat at the back of the classroom and remained relatively quiet. He suggested that Phil join the YPP. Phil’s teacher thought that would get him out of his shell and that he would be good at the work. So as Phil said, “And so, I just stand up and just started doing it. Now I’m going [into] my second year doing it.” During the second year, Phil was asked to participate in robotics as another extra-curricular activity in school. He decided not to participate with robotics, because the YPP outreach work in elementary schools was more important to him: “I was gonna do that [robotics], but I said I’m gonna do this [YPP] ‘cause this is very important to me and I like doing math.” He summarized why the work with YPP was important to him:

> It was important ‘cause I want to help out little kids more. ‘Cause now you don’t see more [people] helping out. They have to go somewhere else to get help, like Sylvan [Learning], and they charge them like 300 [dollars] for one session a month, and we can help them out for free. (February 20, 2007)

When I asked Phil about his view of mathematics literacy, he described it as being able to articulate mathematics in structured way. For him, mathematics literacy was being able not only to read mathematics, but also to communicate it to others:

> Mathematics literacy means to me like basics of reading math in a structured way. In a structured way, what I mean like on the board they say, “Two plus two or four plus four. In a structured way like to read math and know it, and learn it so you can teach somebody else. (February 20, 2007)

In a personal reflection Phil described mathematics literacy as follows:

> Mathematics literacy is when someone has a great knowledge in math skills. The connection to math literacy and community building is that [they] both deal with learning and structuring learning for the community. They both have a wide connection. Both of them [deal] with teaching matters. (Personal reflection)

Phil also explained that to him, mathematics literacy was learning mathematics for oneself. If you do not have the desire to teach mathematics to others, you can teach it to yourself and "keep it in your mind." In other words, mathematics should be "like a pocket reference" for individuals because you do not know when you will need it.

Phil interpreted the YPP mission statement in terms of helping to build stronger students for the future. He stated:

> Well, it means to me … the mission is to get young people from our neighborhoods like neighborhoods round where I grew up at, neighborhoods like [that] to develop something. You know, help kids lower than us, to help them with math. Like to develop like a … stronger future in math in certain neighborhoods. So that's what I think. (February 20, 2007)

Identity

Role Model in Flagway Trainings

Phil constructed his identity as a role model to others in Flagway training. Phil saw his role in executing the goal of mathematics literacy in YPP as supporting individuals in his community who had difficulty in mathematics. As he stated:

> If I know, if I see somebody struggling, I can help that person. 'Cause [mathematics is] always in the neighborhoods, in our community…. They don't graduate. I can help somebody, you know, who's down or something, help them graduate. Like get their math scores up so they [will] be ready for high school or get ready for college. (February 20, 2007)

Even though Phil worked directly with elementary school children, he recognized that some of them needed YPP more than others because of their behavior or their difficulty understanding mathematics. When Phil was asked to elaborate about whom he saw himself helping get their grades up, he explained:

> The kids, what else? Kids who, you know, get a lot of attention in the classroom 'cause they don't do their work, or they might cuss out the teacher. Dem kind of kids. 'Cause

> them most of the kids that do need help in math.… You have some smart you have some that's behind, 'and that's what I want to do. (February 20, 2007)

Phil believed that he could make a significant impact with the kids that he worked with by helping them to learn mathematics. Phil's overall purpose in doing work with YPP was to "help out little kids and just … let them learn how to do math so they can be a leader." He further clarified how he believed he could help children become leaders:

> [YPP will] help them to become leaders because we [are] teaching them. We as MLWs, we can tell them,…"Keep this in your mind." … Like I said, "Keep it as a reference … if you have any problems, just think what we had told you how to do a shortcut to this problem so you can get it." So, that's basically my purpose. (February 20, 2007)

As Phil explained, "keeping this in your mind" is a way of helping children retain important mathematics concepts that they learn from mathematics literacy workers.

One With a Sense of Responsibility

During one of the training days, the CMLWs and MLWs engaged in a social justice activity called Shoe Blind. This activity was designed to get the mathematics literacy workers thinking about inequities in society regarding who gets certain opportunities. The facilitator of the activity selected certain students to be blindfolded, and they were asked to move to one part of the room. Those who were not blindfolded were in a different part of the room. The facilitator then asked the entire group to take their shoes off and toss them to the middle of the room, where they were shuffled around. The entire group, blindfolded and not blindfolded, was then given 30 seconds to locate both their shoes. Those who found their shoes were admitted into college; those who did not find their shoes were not admitted. The group was then debriefed on the activity. The mathematics literacy workers were able to share their perspectives on how students were selected for admission to college and how that made them feel.

The Shoe Blind activity helped Phil to see that despite the advantages that others may have over him in society, he had to take ownership of his own work, stay focused, and be responsible if he wanted to achieve certain goals like getting into a good college. Phil stated:

> Taking off those shoes and just throwing them [to] the middle of the floor. That was memorable to me…because like it was just showing you a way that if you can't succeed in life … that people who don't have their shoes on don't get accepted to college … That made me think.… If I don't get on top of my game, I'm just going to be in another college. You need to be on top of your game.… By staying on top of your game in mathematics is like, staying on top of it 'cause you know … if you [are] in high school, you know you got a test coming up around: SAT and the PSAE [Prairie State Achievement Examination]. You stay on top [of] that game 'cause really colleges are looking for people in the PSAE, they [are] looking for smart kids basically in math, and that's basically it. 'Cause that [is] how you get your scholarship money: Stay on top of your game. (February 20, 2007)

Phil's perspective on what he hoped to accomplish in the training was further shown in a goal-setting activity that he participated in during the training. One of Phil's expected impacts on himself as a result of work with the Flagway game was "to become more goal-oriented and to be more willing to do what it takes in achieving goals." (Archival data, goal-setting form)

Through conversations in the MLW training about teamwork and participating actively in various aspects of the work throughout the semester, Phil began to look at his role differently. He explained that a lesson for him in doing this work was "Don't carry yourself above your measure.… Keep yourself how we expect it." Phil meant that if you are held in high esteem, you should not jeopardize the positive image that others have of you and that you have of yourself. Phil also realized that in order for YPP to be a success at Abelin, CMLWs and MLWs would have to work together and be more proactive in the work at the site. For example, Phil commented on the lack of support some MLWs gave when they were asked to be a part of the YPP production team. The YPP production team was a group of mathematics literacy workers who organized Flagway tournaments so that the games were executed smoothly and successfully. Phil explained:

> Naomi, she want more of you, and she know that you can do it.... Just like DeMarcus.…They gonna want more of you. 'Cause now, we have the production team and don't nobody want to go. And so I think, like, they want more of you. They [are] expecting for our people, expecting for the people who was there last time to go down there again [to the production team meetings]. (February 20, 2007)

Phil realized that he would have to step up and take initiative and be responsible despite other MLWs being unwilling to meet the challenge.

Increasingly Confident Doer of Mathematics

Phil was also an increasingly confident doer of mathematics in the Flagway training. He felt increasingly confident in how he approached the mathematics for the Flagway Game over time. Phil recalled a memorable moment in his mathematics literacy work when he demonstrated instances of leadership. He recalled an experience where he did not feel as familiar with the Flagway content as he would have liked, but then found that he had to teach it to some of his peers who were not familiar with it either. Phil stated:

> Couple of us came over from the school [Abelin], and then we went downtown [to YPP headquarters]. We didn't know nothing. Basically. Just sat right there 'cause we didn't know nothing.… Other kids was looking at us like we was crazy and stuff, and it was like, you have to do this, you have to do that…. Then we got a hang of it, and so, like, we became leaders to them actually, 'cause sometimes they didn't know nothing that we was teaching. (February 20, 2007)

From that experience Phil also stated:

> We thought that we was dumb. But we wasn't. We all came for one reason, to learn and they [the other MLWs from a different site] thought that we was dumb…. They came to us and asked us for help. All of us was leaders. If they needed help, we gave them help, and if I needed help, they gave us help. (February 20, 2007)

Phil also described that as a result of his participation in YPP this semester, he was taking more ownership of the work. He was more active, more willing to participate, and more willing to ask questions about the mathematics he was not sure about:

> Well, this time, [I'm] very active this time. Last time I wasn't active as I was, 'cause I really didn't like know [the Flagway content]. But this time … I'm very active. I'm speaking out if I have a question. I'm not going [to] be sitting like that, being so concerned about it [what others think]. I'm just going [to] speak it out. Last time I didn't speak it out, 'cause they always used to be like, this not right … And I just, like, last time, it wasn't right for me to [speak up]. (February 20, 2007)

Mathematics Strategies and Understanding of Number Concepts

There was one major theme that was revealed in Phil's data: Phil's number and color association.

Phil's Number and Color Association

Phil had some understanding of how to categorize numbers used in the Flagway Game and some understanding of composite and prime numbers. Phil placed the numbers 2 to 21 in these respective color categories and got several of them incorrect. Phil defined *his* red category as all prime numbers. His definition of the yellow category was composite numbers. And his blue category was all odd numbers. Phil's work is depicted in Figure 4.14.

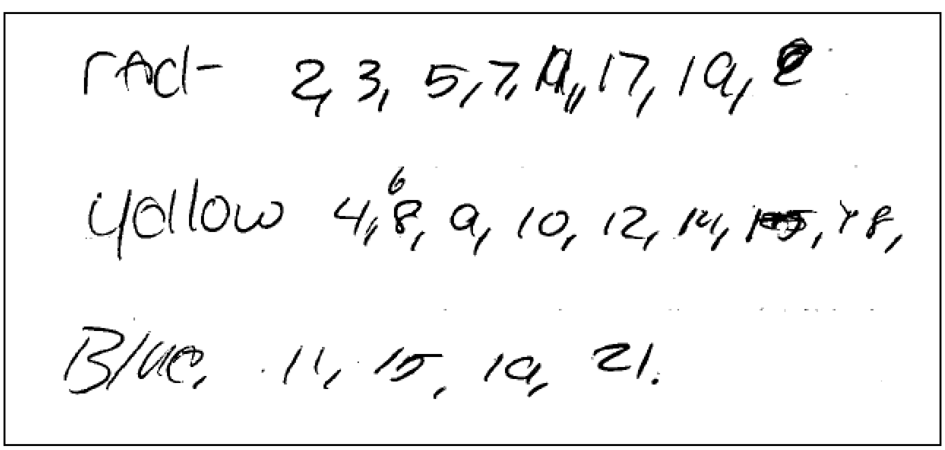


Figure 4.14. Phil's color categorization of 2 to 21.

Phil was asked if the numbers that he had in the blue category were composite or prime numbers. Phil responded that they were not prime and were not composite numbers. His explanation of composite is given in the following dialogue:

> I: You have four numbers in blue: eleven, fifteen, nineteen, and twenty-one. Those numbers are not prime, 'cause if they were prime, they would be in red. And you are saying they're not composite numbers. So what's a composite number to you?
> P: I really don't have [a] definition of *composite,…* but it's one that can be, I say, multiplied by two.
> I: So what is it?
> P: Multiplied. A number that can be multiplied by two or a number [that's] not even. It's not even. That's what I say.
> I: So a composite number is a number you're saying that is what?
> P: Even.
> I: Hmm.
> P: It can have odd numbers. (March 2, 2007)

Although he was asked to review the numbers he associated with each color category, Phil did not recognize that two of the numbers he placed in the blue category, 11 and 19, were also prime and that he had already placed them in his red category. Furthermore, Phil also thought that he categorized all numbers from 2 to 21; however, 13, 16, and 20 were missing from the list. He also placed 6, 10, and 14 in the yellow category when they should have gone in the blue category. Phil repeated the categorization with 35 to 50. Although he captured all these numbers in his categorization, his blue category had two numbers that were prime and one number that was composite, which would belong in his other categorization groups (Figure 4.15). Phil's red category did not include just prime numbers; it also included the composite numbers 32, 33, and 39, that he thought were prime.

Phil could recognize some prime numbers if given to him but had difficulty articulating a definition of a prime. Phil defined a prime number as a "number that can only be divided by one." He was asked to give examples of numbers that fit this definition, and he offered the

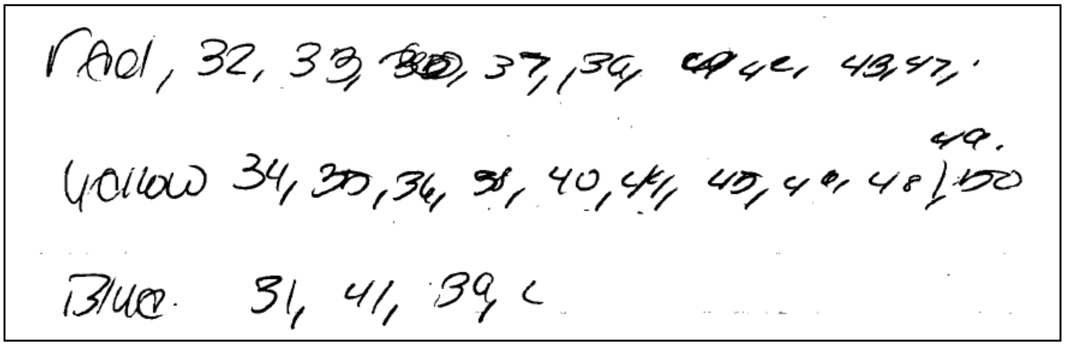


Figure 4.15. Phil's color categorization of 31 to 50.

numbers 11, 19, and 39, even though 39 is not prime.

Phil defined his red category as "divisible by itself; it's going [to] be *A*." He was asked which algebraic form would fit in the red category, and he gave A^2, $A \times B$, $A \times B^2$, and $A \times B \times C$ as examples. Phil stated that his yellow category included numbers of the form $A \times B$ and $A^2 \times B^2$. His blue category had the algebra forms *A* and $A \times B$. He stated that numbers that could go in his blue category could also be in his red category. Phil had created his own definitions for the color categories and placed numbers where he thought they should go. His categorization was only loosely associated with the actual definition of color categories used in the Flagway Game.

Flexibility With Numbers

Factoring in different ways. Phil spoke of his expanded view of factoring as a result of the Flagway Game. He explained that in the past if he were asked to decompose a number like 45, he would only write 9 times 5. He stated, "Before, when I was just like factoring it out, I would just put nine and five. I didn't think about putting three times three." That is, in the past he would not have thought to express the 45 in terms of its prime factors. As a result of Flagway, he said he would now decompose 45 in three ways: using general factors (9×5), using prime factors ($3 \times 3 \times 5$), and using the algebraic form ($A^2 \times B$, or in this case, $3^2 \times 5$).

Phil also stated that as a result of the Flagway Game, he was learning how to interact with others and be more confident:

> I learned that I can, you know, I can interact … more with people. Like, I can really interact with people. But now I'm interacting with people that like are all my best friends now. Interacting with people in like my classroom and stuff. It's like helped me…to make myself an outgoing person. Like to make myself speak up. (March 2, 2007)

Phil also explained that YPP was a really good experience for urban youth because many children do not participate in out-of-school activities:

> [YPP helps] urban youths … because like some kids don't really have nothing to do after school, just do homework. And then actually like, it brings kids, you know, it brings kids out, you know, to support each other in what they really know about math and stuff. [It] acts like a support group. (March 2, 2007)

Summary of Phil

Phil, a MLW, embodied the identity in the context of the Flagway training of a role model, one with a sense of responsibility, and an increasingly confident doer of mathematics. He looked at himself as a supporter of those in his community and in particular of children who have difficulty in mathematics and may also have behavior issues in their classes. He believed that through his work in YPP, he could help those children become leaders. Phil also developed a sense of responsibility as a result of his work in YPP. Through his activities during Flagway training, he realized that to achieve his own goals like getting into college, he had to take responsibility for his work and be proactive. He was also an evolved doer of mathematics in Flagway training. His confidence in doing the mathematics of Flagway changed. Through engagement with other MLWs from other sites, Phil realized that he too could do the mathematics, and as a result, he saw himself as a leader.

Phil demonstrated some understanding of the numbers in the Flagway Game, but he was also incorrect. Phil had difficulty determining the color categorization and the definition of composite and prime numbers. Phil created his own definitions of the color categories to determine where the numbers 2 to 21 and 35 to 50 should be placed.

Phil explained that the mathematics he learned in Flagway had expanded the way he factored numbers. Before Flagway, he would decompose the number into general factors, which are any pair of factors whether prime or not. Now he looked at decomposing numbers in three ways: general factors, prime factors, and the algebraic form. Phil also stated that through the work that he had engaged in, he had more confidence to speak up in class.

In the next section, the findings from cross-case analysis are provided which details a summary of the similarities and differences identified for the four cases.

Cross-Case Analysis

Cross-Case Analysis of Identity

In this section, findings from the cross-case analysis of the data presented in the earlier part of this chapter is given relative to the first research question:

> *What identities do African American college mathematics literacy workers and high school mathematics literacy workers have of the Young People's Project Chicago, in the context of the Flagway training?*

For each of the common themes of identity found across participants, I specifically discuss their similarities and differences.

For this category, analysis for all four partipants relates to their comments in the initial interview and what was observed in the Flagway Game workshop training. The summary of the identity themes across the four participants can be found in Table 4.1. The table provides each theme, the participants that embodied the theme, and a general description of each theme. There were four major themes of identity across participants; (a) agent of change, (b) confident doer of mathematics, (c) increasingly confident doer of mathematics, and (d) role model in Flagway training.

Table 4.1. Summary of Themes of Identity Across Participants

Major Themes	Participants	Description of Themes
Agent of Change	- Naomi - DeMarcus - Charlene	Someone who purposely works toward creating some kind of social, cultural, or behavioral change in society or in others through his or her work or actions.
Confident Doer of Mathematics	- Naomi - Charlene	Someone who came to YPP confident in his or her ability to do mathematics.
Increasingly Confident Doer of Mathematics	- DeMarcus - Phil	Someone who developed confidence in themselves and an enthusiasm to do mathematics over time through engagement in the Flagway training.
Role Model in Flagway Training	- Naomi - DeMarcus - Phil	A person who serves as an exemplar of positive behavior in one or more contexts and who believes their role is to demonstrate leadership or guidance.

Agent of change. Three out of the four participants saw themselves as an agent of change. The similarities in the way these participants talked about being an agent of change could be characterized collectively as making some type of social change. For Naomi, it was improving the welfare of others by promoting consciousness in the community. For DeMarcus it was giving children a better educational foundation. For Charlene, it was by creating enjoyable experiences for others when doing mathematics. In looking at the theme agent of change across participants, there was a range in how they viewed what they wanted to change. The participants identity as agents of change could be viewed from a localized perspective (changing how a specific thing is experienced, e.g. mathematics) to a broad perspective (changing the agency of others, e.g. helping others to take ownership and promoting awareness of issues in the community).

Both Naomi and DeMarcus also spoke explicitly about how Black people and low-income communities have been historically disenfranchised due to lack of education and access to education. Naomi described the importance of helping these communities exercise their full human potential. DeMarcus also described improving the lives and the achievement potential of inner city kids to remedy social inequalities.

The differences in the way the participants talked about being an agent of change could be characterized as the figures in life they wanted to become. Naomi viewed herself as an activist and wanted to be "some sort of humanitarian." She appeared to look at her work in a broader context than what took place in the Flagway Game training. DeMarcus wanted to become a teacher. At times, he referred to his work from a broader perspective but it centered on how he wanted to change education. Charlene considered teaching as a career pursuit, but was not certain that she would do this in the future. She spoke specifically about what she wanted to accomplish when she worked with her peers and went she went to elementary schools to work with children as it related to mathematics.

Confident doer of mathematics. While all of the participants were considered to be doers of mathematics, two out of the four participants, Naomi and Charlene, had the identity, confident doer of mathematics. The similarities in how they embodied this identity could be characterized as their intrinsic motivation to do mathematics. These participants indicated that they have always possessed a willingness to do mathematics. The participants also believed that mathematics was a challenging discipline to study but chose to engage in it anyway. Both participants also expressed a general sense of enjoyment that they felt when they did mathematics.

The differences in the way particpants viewed themselves as confident doers of mathematics could be characterized as the goals they each had when they engaged in mathematics. Naomi's confidence in doing mathematics gave her opportunity as a goal. Naomi understood that possessing strong skills in mathematics was an invaluable tool. She spoke of the importance of minorities being skilled in mathematics because it enabled them to excel. She also suggested that just by having mathematics skills opened doors of opportunity. Due to her ability to do mathematics she was able to attain academic opportunities. For Charlene, her goal was maintaining a certain mindset when doing mathematics, "it becomes easy, because I make it fun." Even when the mathematics became challenging, she tried to maintain a positive outlook about the discipline. In these two conceptions within the theme, confidence in doing mathematics, one participant experienced academic benefits because they could confidently do mathematics, while the other experienced emotional benefits when doing mathematics.

Increasingly confident doer of mathematics. The other two participants, DeMarcus and Phil, viewed themselves as increasingly confident doers of mathematics. This increased confidence in doing mathematics was developed over time and grew from an initial uneasiness. For DeMarcus, his discomfort came from earlier experiences in his schooling. For Phil, his discomfort was associated with some of his experiences in YPP, in an earlier Flagway Game training. Both participants in some respects recoiled from doing mathematics when they were unsure or it appeared to be too challenging for them to handle. Both participants also talked about their apprehension in doing mathematics as a perception of themselves relative to how they viewed their peers or thought their peers viewed them. DeMarcus perceived his peers to be better in mathematics than he was. Phil talked about his peers looking at him awkwardly before teaching the Flagway Game. Phil further reinforced this by saying, "they… thought we was dumb." Finally, both participants made a decision for themselves that they would be more confident in how they would approach mathematics and they both attributed this change with their work in Flagway. They both wanted to take more ownership of the work and be more willing to participate in solving problems.

There was one major difference in how the participants viewed being increasingly confident doers of mathematics. DeMarcus considered his status as an increasingly confident doer of mathematics relative to the other kids that he worked with. He empathized with students who did not have the willingness to figure out problems given to them. DeMarcus was also uncertain on how he could influence kids who lacked a desire to do mathematics. For Phil, he talked specifically about what he could do to be more mathematically confident.

Role model in flagway training. Three out of the four participants, Naomi, DeMarcus, and Phil, viewed themselves as role models in Flagway trainings. They saw themselves as leaders, mentors, exemplars, and viewed their role as providing guidance for other mathematics literacy workers when they struggled in mathematics and to execute the work. The similarities in how the participants viewed themselves as role models are that they each thought it was important to model a certain kind of positive behavior when doing mathematics literacy work. They each believed that this would inspire others to do the same. For Naomi, she had very clear views of what being an effective mathematics literacy worker looked like and she wanted both CMLWs and MLWs she worked with to work towards adopting these behaviors so that they could also do good work. DeMarcus also modeled positive behavior, which was his positive disposition and willingness to do mathematics. He talked explicitly about leading by example and hoped students would feed off of his positive energy as they engaged in the mathematics so that it could be more of their own. He adopted the "if I can do it, you can do it" attitude. From my observations, Phil did not explicitly model a certain kind of positive behavior, but he felt it was his job to help kids retain important mathematics concepts that they were taught by mathematics literacy workers that they would need later. He also believed that his role was to support the students, who had a more difficult time in school than others because of their behavior. These participants, in some sense, looked outside of the Flagway training. They knew that they were preparing mathematics literacy workers for something bigger than the Flagway training. They also knew that it was their job to make sure that mathematics literacy workers were equipped to handle what they had to do when the training was completed and when they started their work in elementary schools.

Differences could be found in what the participants decided to focus their energy on as role models. For Naomi and DeMarcus, they described what they could do in Flagway trainings and Phil described what he felt he could do in schools. Naomi chose to focus on demonstrating the importance of improvisation. She believed it to be an important skill that mathematics literacy workers should possess. She also demonstrated the importance in having a deep understanding of the Flagway content. When necessary, she also demonstrated the necessity in changing the focus of the workshop for that day to ensure that everyone understood certain concepts. DeMarcus focused specifically on how other mathematics literacy workers viewed the mathematics they did. He felt like he could relate to the other mathematics literacy workers and tried to put himself in their position when they struggled. He consistently listened to their concerns and tried to make modifications in the training when necessary. Phil felt that his role was to support individuals in school who may be disruptive in their classes because they did not understand the mathematics. As a role model, Naomi, DeMarcus, and Phil also characterized their view of their roles differently. Both Naomi and others saw her as an authority in Flagway trainings. She thought this to be problematic at times because she did not want mathematics literacy workers to rely only on her knowledge for solutions to problems. For DeMarcus, he viewed his role model status as a reciprocal relationship. He believed that he could learn just as much from other mathematics literacy workers as they could from him and he welcomed that kind of engagement. For Phil, his identity as a role model was more focused on how he could support other students, not necessarily in Flagway trainings, so that they could become leaders in the future.

Cross-Case Analysis of Mathematics Strategies and Understanding of Number Concepts

In this section, findings from the cross-case analysis of the data presented in the earlier part of this chapter is given relative to the second research question:

> *What are the mathematics strategies used by college mathematics literacy workers and high school mathematics literacy workers in number categorization of the Flagway Game and their understanding of these number concepts?*

For each of the common themes of mathematics strategies and understanding of number concepts that were found across participants, I discuss their similarities and differences. For this category, analysis for all four partipants relates to their comments in the second interview which included the three mathematical tasks. The summary of mathematics strategies and understanding of number concepts across the four participants is illustrated in Table 4.2. The table provides each theme, the participants that embodied the theme, and a general description of each theme. There were two major themes of mathematics strategies and understanding of number concepts across participants; (a) memorization for color association and (b) flexibility with numbers.

Table 4.2. Summary of Themes of Mathematics Strategies and Understanding of Number Concepts Across Participants

Major Themes	Participants	Description of Themes
Memorization for Color Association	- Naomi - DeMarcus - Charlene	Memorization was used as a strategy by three of the participants to categorize number used in Flagway.
Flexibility With Numbers	- Naomi - DeMarcus - Charlene - Phil	Participants demonstrated various levels of flexibility with numbers. They were able to articulate and demonstrate several connections between natural numbers and prime factorizations they had.

Memorization for color association. Three out of the four participants described using a memorization strategy to categorize numbers into the three-color categories of the Flagway Game. Naomi demonstrated using two memorization strategies. For the first, she could readily associate numbers 2 through 21 and 35 through 50 with their respective colors. Naomi also used a second memorization strategy, which relied on her knowledge of the prime factorization definitions. Naomi just decomposed numbers enough to determine if it would go into the red, yellow, or blue category. For DeMarcus, he was able to memorize the color association for numbers 2 through 21. Charlene also used a memorization strategy to remember the categorization of the number 2 through 11. Looking across the three participants they were all able to correctly categorize the numbers 2 through 11 from memory with ease. For numbers like 2 through 21, there was also a similarity in the way Naomi and Charlene articulated their thinking about each category. They did not reference the formal mathematical definition of each category. Instead they described it as all prime numbers go in red, a number raised to a power goes in yellow, and two different numbers goes into blue.

A distinction in the participants was that one participant, Naomi, described having goals when deciding which memorization strategy to use. DeMarcus and Charlene did not describe goals when decomposing numbers. For Naomi, the memorization strategy that she used depended on what she was trying to accomplish at the time. If she tried to find the algebraic form of a number, she would decompose the number. If she tried to determine the color output, she would decompose the number enough to determine which category it would go in. Naomi also admitted that for numbers 2 through 10, she did not readily make a connection to mathematics for those numbers since they were committed to her memory.

Flexibility with numbers. Across all four participants, there was a common thread in their descriptions of how they described the increased flexibility they had in factoring and their knowledge of numbers as a result of the Flagway Game. Naomi believed she had increased numbers sense and could determine more information about a specific number in question because she had more understanding of the numbers. DeMarcus was able to decompose large numbers that he was not as familiar with into its prime factorizations. Charlene was able to find the prime factor of numbers quickly since she practiced decomposing numbers often. Phil stated that he was able to factor numbers in three distinct ways; general factors, prime factors, and algebraic form.

Two of the participants, Naomi and DeMarcus, spoke about understanding more about low prime numbers as opposed to high prime numbers even though this language was not explicitly used in Flagway training. For both of them, low primes were considered to be numbers that were between 1 and 12. High prime numbers were prime numbers greater than 12. Naomi and DeMarcus also used mathematical rules they learned in their prior schooling in order to decompose numbers that they were not as familiar with.

Differences across the participants could be characterized in how they described their flexibility with numbers. For Naomi, flexibility with numbers was described as having more knowledge about numbers. For DeMarcus, flexibility with numbers was described as being able to handle any number, whether he was familiar with it or not. For Charlene, flexibility with numbers was described as quickness. For Phil, flexibility was described as factoring in different ways.

Another difference between participants is that Naomi spoke of the connections she was able to make about natural numbers she was not sure she was aware of before. For instance, Naomi was the only participant that articulated that she finally understood that for all numbers greater than 1, they could be expressed as product of prime factors and placed into one of the three color categories based on how its prime factorization looked. None of the other three participants described this.

In the next chapter, Chapter 5, I will respond to the individual research questions of the study. I will also provide a discussion of the case study within the framework of communities of practice and from a critical race theory perspective. Finally conclusions for the study along with implications for future work are also provided.

CHAPTER 5

DISCUSSION AND INTERPRETATION OF CASE STUDY FINDINGS

> In order for us as poor and oppressed people to become a part of a society that is meaningful, the system under which we now exist has to be radically changed. This means that we are going to have to learn to think in radical terms. I use the term *radical* in its original meaning—getting down to and understanding the root cause. It means facing a system that does not lend itself to your needs and devising means by which you change that system. That is easier said than done. But one of the things that has to be faced is, in the process of wanting to change that system, how much have we got to do to find out who we are, where we have come from and where we are going…. I am saying as you must say, too, that in order to see where we are going, we not only must *remember* where we have been, but we must *understand* where we have been. (Ella Baker, quoted in R. P. Moses & Cobb, 2001, p. 3)

This chapter will individually address each research question and the respective subsidiary questions. A discussion of the case findings in the context of communities of practice (CoPs) and the three modes of belonging is provided along with a discussion of findings from a critical race theory perspective. The conclusion of the study, along with implications for future practice, future research, and future theory building are also presented. The study was guided by the following research questions:

1. What identities do African American college mathematics literacy workers and high school mathematics literacy workers have of the Young People's Project Chi cago, in the context of the Flagway training?

    a. What led African American college mathematics literacy workers and high school mathematics literacy workers to participate in the Young People's Project Chicago?

    b. What role do college mathematics literacy workers and high school mathematics literacy workers see themselves having in their local communities?

2. What are the mathematics strategies used by college mathematics literacy workers and high school mathematics literacy workers in number categorization of the Flagway Game and their understanding of these number concepts?

The Research Questions

The purpose of this study was to examine how the experiences of African American college mathematics literacy workers (CMLWs) and high school mathematics literacy workers (MLWs) within a community of practice, namely the Young People's Project (YPP) Chicago, influence the identities they have and inform how they categorize numbers used in the Flagway Game. The first research question was divided into two subsidiary questions. I address each research question and the two subsidiary questions individually.

Research Question One

> *What identities do African American college mathematics literacy workers and high school mathematics literacy workers have of the Young People's Project Chicago, in the context of the Flagway Game training?*

There were some similarities and differences in identity across all participants. Participants saw themselves as agents of change. They could be characterized collectively as making some sort of social change, but conceptualized this identity differently. Naomi viewed herself as an activist and wanted to improve the welfare of others by promoting consciousness in the community. DeMarcus saw himself as an agent of change in that he wanted to make a difference in the educational lives of students in the inner city. Charlene viewed herself as an agent of change because she believed that through her work with students, she could help them enjoy and experience mathematics in a different way.

All participants saw themselves as doers of mathematics. Two participants were confident doers of mathematics, and two others were increasingly confident doers of mathematics. Naomi and Charlene came to the YPP with a high comfort level in doing mathematics, whereas DeMarcus's and Phil's comfort level in mathematics developed.

Participants saw themselves as role models in Flagway training. They looked at their role as a form of leadership, mentorship, and guidance to other students she worked with. Naomi saw herself as a role model and tried to demonstrate what it meant to be an effective mathematics literacy worker. DeMarcus saw himself as a role model in Flagway training in that he led by example and wanted to show MLWs that although the mathematics was challenging at times, if you stick with it, you will eventually understand it. Phil felt it was his job to help kids retain important mathematics concepts that they learned from mathematics literacy workers that they would need later and help them become leaders.

Charlene viewed herself as one who could persevere. In this respect, the young children she worked with at elementary schools frustrated her at times because of their lack of focus, but she knew she had to modify her approach so that she could reach them. Phil viewed himself as one with a sense of responsibility. He also believed that to achieve the success he wanted in school and in the YPP, he would have to step up and be more responsible and proactive.

The identities found in CMLWs and MLWs are in support of research that have documented other outcomes that were associated with students involvement in after-school program initiatives that were not limited to academic achievement. These findings included, motivation to succeed in school and an increased commitment in learning by students (Barber, Eccles, & Stone, 2001; Mahoney, Cairns, & Farmer, 2003), a higher self-esteem and improved emotional adjustment and interpersonal skills (Barber et al., 2001; Gerstenblith, Soule, Gottfredson, Lu, Kellstrom, & Womer, 2005; Mahoney, 2000; McLaughlin, 2000) as a result of student participation. Findings from these studies have also shown gains in adolescents' initiative, communication, leadership, and connection to the community (Larson, 2000; Youniss, McLellan, Su, & Yates, 1999).

Subsidiary Question One

What led African American college mathematics literacy workers and high school mathematics literacy workers to participate in the Young People's Project Chicago?

Although each participant of this study had his or her own rationale for gaining membership in the YPP Chicago as a mathematics literacy worker, the overarching impetus was to give back to the community in some way. One of the participants, Naomi, wanted to have a better understanding of the students she worked with from another after school program she participated in. She enjoyed working with others and wanted to understand the mathematics the young people she worked with were learning. Because she enjoyed it so much, she decided to continue her work with YPP. DeMarcus, the other CMLW, had three reasons for participating in YPP Chicago. He wanted to acquire teaching experience, take on the challenge for himself of learning the mathematics used in the Flagway Game, and to help in improving the lives of inner city kids. The two participants who were MLWs were recommended for the program by friends or by a teacher. Charlene's friends explained how much fun they had in the program. Because she liked to teach, help people, and do mathematics, she thought the program would also be a good fit for her. For Phil, his teacher believed that becoming a mathematics literacy worker of YPP Chicago would help him break out of his shyness and that he would be good at doing the work. Despite the challenge in doing mathematics, all participants shared the belief that mathematics was a necessity for young people to learn in the local community because it afforded individuals access to a number of opportunities later in life.

Some of the reasons that led to membership in YPP, cited by participants of this study, are highlighted in findings from other studies that have examined the factors that contribute to youth participation in community or school-based activities. These included friend endorsements of the after school activities (Huebner & Mancini, 2003), activities found to be fun as motivation for participation (Gambone & Arbreton, 1997), opportunities to learn (Strobel, Kirshner, O'Donoghue, & Mclaughlin, 2008), and the acquisition of new skills and involvment in the community (Perkins, Borden, Villarruel, Carlton-Hug, Stone, & Keith, 2007). Also in accord with McLaughlin's (2000) findings, youths that participated in after school programs in urban settings wanted to participate in something greater than themselves. These students selected programs for themselves where they could make an impact in their community, have some autonomy in decision making, have a learning environment with committed adults, and consistently reflect on how well the program was going for them.

The findings of this study also supports research on youth development programs suggesting that these types of initiatives have short and long-term benefits to young people. Researchers have reported a positive correlation between students participating in after school inititiatives and their academic achievement (Broh, 2002; Guest & Schneider, 2003), their social adjustment, and high school completion (Mahoney, 2000). Nicholson, Collins, and Homer (2004) have reported additional academic benefits for young people who participate in youth development programs. They are more likely to experience the six C's, which are as follows:

> Providing secondary support system (connections), helping them develop a positive identity (confidence), a sense of belong (caring), helping them develop skills and resources for choosing healthy options over risky ones (competence), creating vehicles for which to give back to the community (contribution), and encouraging a sense of responsibility for oneself and others (character). (p. 58)

Subsidiary Question Two

What role do African American college mathematics literacy workers and high school mathematics literacy workers see themselves having in their local communities?

All of the participants of this study collectively believed that their role was to help uplift young people in the community to achieve some form of mathematics literacy through the Flagway Game and their interaction with them. Each participant spoke about this empowerment in a variety of ways. Naomi saw her role as being proactive in helping others understand mathematics while shifting how mathematics is perceived in the local community. Naomi also spoke of the importance in minority and low-income communities having access to education as a right, in order for them to exersice their full human potential. DeMarcus felt that his role in YPP was to build competent and self-sufficient students. DeMarcus also believed that his job was to help young people be prepared for situations that may arise by having the confidence to meet any challenge, no matter if they succeeded or failed. In his own conception, DeMarcus reiterated how education was used as a tool to disenfranchise Black people. For him, it was the combined effort of "striving for social equality and improving the lives and the achievement potential for kids" that fueled his efforts in the community and in becoming an educator. Charlene believed that her role was to build and to encourage younger people to understand mathematics, by thinking about it differently. Charlene also believed that her job was to make mathematics more enjoyable for students. Phil believed that his role was to help kids have a stronger future in mathematics.

Participants of this study also saw their role in the community as making mathematics enjoyable while it is being practiced. All of the participants of this study perceived mathematics as enjoyable. This was one of their motivations for continued engagement in mathematics literacy work and the Flagway Game.

Educators and individuals engaging students in mathematics might consider the enjoyment students seek when doing work in the activities they participate in inside of schools and outside of schools. The Flagway Game helped to create a context for engagement in mathematics because it provides a competitive component in how students do and learn mathematics. Some students enjoy competition and they also enjoy subjects that enable them to have fun while learning. These findings are supported in Moyer's (2001) study where she found that students perceived mathematics to be fun and wanted to learn when they used activity-based tools like manipulatives or when they were actively playing a game. As she points out, in these instances, "students were interested, active, and involved" (p. 186). Further, Boaler's (2000) findings also suggest that students who find mathematics enjoyable are more likely to continue to study it in later years. Boaler also found that students had a greater appreciation for subjects that connected them to "normal things in life" (p. 386) where they could find meaning in people, places, and events. Other scholars also suggest that students welcome connections to mathematics and life by exploring problems (Burton, 1999) and by encouraging discussion and argument (Wood, 1999).

Research Question Two

> *What are the mathematics strategies used by African American college mathematics literacy workers and high school mathematics literacy workers in number categorization of the Flagway Game and their understanding of these number concepts?*

All of the participants used some sort of memorization strategy to help them categorize some of the numbers used in the Flagway Game. Naomi used two types of memorization strategies in her categorization scheme; one where she used color association to determine the color category in which to place a number and the other where she memorized certain numbers she was not as familiar with so as to categorize them. Naomi's number flexibility was enhanced as a result of the Flagway training. She was also able to better articulate some of the issues she had with her early number concepts. She also explained that because of the work she did in Flagway, she had gained a more clear understanding of prime numbers and how every natural number is composed of a unique set of primes.

DeMarcus used memorization strategies to determine which number was assigned to a respective color. He was familiar with the color categorization of 2 through 21 and used no mathematical reasoning in assigning numbers to colors. As a result of his engagment in the Flagway Game training, DeMarcus believed he had increased number sense and was able to come up with a prime factorization strategy that helped him to find the prime factorization of numbers he was not familiar with. He also explained that as a result of his work with Flagway, his approach to multiplication had shifted, and his curiosity to do mathematics had been inspired.

Charlene used memorization strategies to categorize 2 through 11, but had difficulty categorizing some numbers that were larger than 11. She demonstrated some understanding of numbers used in the Flagway Game. Charlene could recognize prime numbers when given to her, but had some difficulty articulating the definition of prime. Because of the understanding she believed she developed, Charlene came up with her own definition of number and color association for each category. As a result of her work in Flagway, Charlene explained that she had developed a quickness in decomposing numbers.

Phil demonstrated some understanding of numbers used in the Flagway Game. He had difficulty determining the color categorization and the definitions of composite and prime numbers. He also reported an increased number flexibility in the way that he factored numbers. As a result of Flagway, he now looked at factorization in three different ways: general factorization, prime factorization, and prime factorization in an algebraic form. Phil described general factorization as being able to express a number in multiple factored forms (e.g., $16 = 4 \times 4$ and $16 = 2 \times 8$).

Discussion of Case Study Findings

In this section, a discussion of the case study findings is guided by the research questions and based on Wenger's (1998) communities of practice (CoPs) and the three modes of belonging: engagement, imagination, and alignment. In this analysis I discuss how engagement, imagination, and alignment mediated the identities of college and high school mathematics literacy workers. I also discuss trajectories and explain how trajectories helped them in their learning and understanding of numbers used in the Flagway Game. I also analyze my findings from a critical race theory perspective, highlighting counternarratives, where mathematics literacy workers worked towards mathematics literacy for liberation. My focus in this analysis is the MLW Flagway training session; however, I do refer to other contexts in which mathematics literacy workers were engaged, such as the CMLW training and the elementary schools where they implemented the Flagway Game.

Engagement

The different identities of the CMLWs and MLWs were influenced by the levels of engagment in practice they each had in the workshop training. Engagement is an ongoing process of negotiation of meaning, formation of trajectories, and construction of shared histories of practice. Engagement is an important process in how we come to see ourselves, and the way in which one engages defines belonging. The level at which participation occurs determines similarities, differences, and shared repertoires in how things are done in practice. In the Flagway training, the CMLWs and MLWs worked together with a common purpose of doing mathematics differently and building a community among themselves so that they could rely on one another when working with children.

The CMLWs and MLWs saw themselves as individuals who could make a difference in how mathematics was taught to others both in workshop training and at elementary schools implementing the Flagway Game. Although they shared the collective identity of, “mathematics literacy workers,” they each interpreted this position differently and took on unique roles doing and delivering mathematics. The CMLWs’ and MLWs’ level of engagement varied substantially because their priorities in workshop training were different. Nasir (2002) points out, “Learning, then, involves coming to new ways of engaging in practice. As participants’ engagement shifts, so does the nature and practice of self” (p. 228). The CMLWs had the responsibility of preparing the MLWs during training as part of their practice, whereas the MLWs were being prepared to work with elementary school students. The CMLWs were responsible for creating activities that would be used in training by the MLWs and eventually at elementary schools. The MLWs were responsible for implementing the activities they learned in training at elementary schools. Because of the different priorities that the CMLWs and the MLWs held, their various identities emerged from different goals.

Differences in engagement between the CMLWs and MLWs can be found in the case studies. The CMLWs and MLWs operated at two levels of engagement. The ways in which the CMLWs and MLWs negotiated meaning when playing the Flagway Game and their purpose overall in the YPP were distinct. The CMLWs were more focused on keeping the MLWs on task in training and did not engage in much talk that was not focused on the Flagway content. The CMLWs also paid greater attention to the mathematics used in the Flagway Game. They spoke about what they learned about themselves because of the mathematics they practiced. The

CMLWs elaborated in detail about the many revelations they had about themselves, their own understanding of number concepts, and the lack thereof from their formative years in mathematics. The CMLWs also reflected deeply and were able to articulate both their ability and inability to engage in mathematics, referring consistently to prior schooling experiences. Naomi and DeMarcus tried continuously to understand what aspects of Flagway were difficult for them and the MLWs. They then used this knowledge to improve at their practice when working with MLWs. Both Naomi and DeMarcus knew that MLWs would turn to them for clarification and guidance when they were unsure about the mathematics content. As a result, both Naomi and DeMarcus made it their priority to develop a deep level of understanding of the mathematics used in Flagway so that they could be seen as an expert and an exemplar. Expert and exemplar reflect the identities that we see constructed in Naomi and DeMarcus as role models in Flagway training.

In contrast, although learning the Flagway Game was important to the MLWs, their negotiation of meaning and level of engagement were focused more on the social aspect of the workshop training and less focused on how they understood the mathematics used. The MLWs used Flagway training as a space for building relationships in the community after their school day was over and as a context for relating to one another and talking with their peers about their day. Phil stated, “I really wasn’t close to certain people, but now, we all close to each other. We all best friends.” In training, the MLWs moved in between talk that was focused on Flagway and talk about things that had to do with their interactions during their school day. The MLWs did not use Flagway to make connections to mathematics from their earlier years in school, nor did they discuss in detail the way Flagway influenced how they thought about mathematics. Instead, the MLWs spoke of learning how to work well with others, modifying their attitude within the

CoP, staying focused and not giving up on the work even when frustration arose, being more responsible overall as mathematics literacy workers, modifying their willingness to participate when asked to do specific tasks, and explaining the ways in which the work in the YPP and Flagway prepared them for the future. This claim is supported by the themes that emerged in Charlene's and Phil's case studies, where they constructed the identity of one who perseveres and one with a sense of responsibilty, respectively.

A shared history of experience in practice influences engagement and also enables the contruction of identity. A shared history of experience represents a common practice that is collective to all mathematics literacy workers not only at the Abelin training site but also at other sites in Chicago. The CMLWs and MLWs worked to cultivate a shared history of experience during training through the number of hours they spent together after school and through the types of activities they engaged in every day they met. During training, the CMLWs and MLWs participated in activities like teambuilders (e.g., Community of Hands), social justice activities (e.g., Shoe Blind), debriefings (e.g., reviewing each activity as they played out in training), and the Flagway Game. These activities gave the CMLWs and the MLWs an opportunity to express themselves in different ways and to explore games that other YPP members created. As they engaged in these activities, their participation changed and their identities evolved. These activities provided a context to give voice to young people who wanted to talk about everyday challenges they faced growing up in their neighborhood. In doing these activities, trajectories of what mathematics literacy work entailed were formulated. This common understanding of mathematics literacy work created cohesion within the CoP so that both the CMLWs and the MLWs could share common experiences and build a connection with one another. In some respect, through this shared history of experience, the CMLWs and MLWs *became and felt* more and more like a community of "mathematics literacy workers," which is how they often referred to themselves in training.

Imagination

In a CoP, imagination is a critical component in identification because it transcends practice. Imagination is an essential element of our experience in the world and how we come to make sense of our place in it. It is the ability to create images of the world and of the self we hope to become by imagining something new and different for ourselves. Wenger (1998) explains that "imagination requires the ability to dislocate participation and reification in order to reinvent ourselves, our enterprises, our practices, and our communities" (p. 185). Imagination can create affinities to social causes, organizations, and groups of people. In this sense, identity rests not only on practice but is an expansion of time and space and can take on new dimensions beyond engagement. In the local community, the CMLWs and MLWs saw themselves as creating new experiences for others in mathematics and in education. The CMLWs and MLWs saw themselves as agents of change and imagined themselves actualizing that identity in a number of ways.

The imagination of the CMLWs allowed them to connect their work in Flagway to the broader mission of the YPP. The CMLWs were more likely than the MLWs to link their practice in training to a broader community of mathematics literacy workers in Chicago and also to the national efforts of the YPP and the Algebra Project. Both CMLWs saw themselves as being part of a social movement in mathematics education that empowered youth in communities near and far. This view can be seen in Naomi's and DeMarcus's interpretations of the YPP mission statement and their alignment with the work of Bob Moses, both on a national level (e.g. Quality Education as a Civil Right initiative) and through his work outlined in the book *Radical*

Equations (R. P. Moses & Cobb, 2001). It can also be seen in their explanations of the impetus for becoming a part of the YPP. Naomi wanted to better understand the students she worked with, and DeMarcus wanted to acquire experience in teaching. The CMLWs also connected the importance of doing their work to specific social problems they witnessed in school mathematics, like students failing standardized mathematics examinations and students not being taught mathematics effectively. The CMLWs used imagination to create life trajectories (Nasir, 2002) for themselves of what they hoped to become once they graduated from college. Specifically, Naomi explained that through engagement in her work with youth, both in the YPP and through other organizations she has worked with, she knew that she wanted to be "some sort of humanitarian" or social activist. DeMarcus explained that as a way of combating inequities in education he saw himself becoming an educator and was leaning towards becoming a teacher in the Chicago public schools. Both Naomi and DeMarcus believed that their experience in the YPP was a stepping stone to the work they wanted to accomplish. They also believed that to create change in schools and society, they had to be a part of *some* change effort.

The MLWs also saw themselves as agents of change and as supporters of others. First, they believed that they could help children they worked with have experiences in mathematics that were fun. They envisioned mathematics as a subject that, while challenging, could also be very exciting if communicated in a specific way. The MLWs envisioned themselves transforming how children enjoyed and engaged in mathematics. Charlene was confident in her ability to do and explain mathematics to others and imagined herself as possibly becoming a teacher. She believed that her work in the YPP helped her practice the skills she needed to pursue teaching if she decided to explore that endeavor. She connected her practice with that of a teacher and used that image of herself in Flagway when working with her peers and with children at elementary schools. Phil envisioned himself helping to create leaders in the community. Although he offered no definitive way of accomplishing that goal, he saw himself making an impact on the children that he worked with through his support of them and being a role model.

Alignment

An important aspect in the construction of identities in a community of practice is the work of alignment. The work of alignment enables imagination to be interpreted as concrete actions.

> Alignment requires the ability to coordinate perspectives and actions in order to direct energies to a common purpose.… Alignment requires participation in the form of boundary practices and people with multimembership who can straddle boundaries and do the work of translation. (Wenger, 1998, p. 187)

Alignment is the ability to take visions of self and transform them into relevant practice.

There were varied levels of alignment among the CMLWs and the MLWs. For the CMLWs, alignment constituted identity in Flagway training when they drew upon their goals of becoming a humanitarian and an educator. The CMLWs structured their practice to align with these goals. For instance, because Naomi wanted to become a humanitarian and an activist, she structured her practice in the training to raise the social consciousness of other mathematics literacy workers through social justice activities. She also structured her practice to include the broader purpose of the YPP, reinforcing the need for mathematics literacy in the local community and highlighting the importance of children thinking critically about numbers. DeMarcus's aspiration to become an educator helped to structure his practice in Flagway as being sensitive to the differing personalities and learning styles of MLWs so that he could be effective in his facilitation of lessons with them. He also structured his practice in guiding literacy workers when difficulty arose in the Flagway content. Finally, in constructing himself as a role model, DeMarcus also structured his practice in building confident students by working one-on-one with MLWs when the need arose.

The MLWs did not use the work of alignment as readily as the CMLWs in their practice. Charlene, did not necessarily structure her practice in Flagway training with that of a teacher. She did however reflect on prior experiences she had with a student at an elementary school where she demonstrated *teacher-like* qualities like patience, being firm, and working with students who were not always willing to engage in the work. Phil did not explicitly indicate what future plans he had for himself. He did indicate that in the previous year when he participated in YPP, he was shy and afraid to speak up. He did structure his practice in the training where he had more confidence to participate more fully in activities with others when asked to do so.

Trajectories in Learning and the Understanding of Numbers in the Flagway Game

Wenger (1998) explains, "Identities are defined with respect to the interaction of multiple convergent and divergent trajectories" (p. 155). As a way of negotiating the present, our identities integrate the past and the future. In CoPs, there are a number of trajectories operating simultaneously and independently that assist in learning and understanding. Trajectories operate as a tool for deciphering what is important to learn and what should be left on the sidelines. Wenger also explains, "Understanding something new is not just a local act of learning. Rather, each is an event on a trajectory through which they give meaning to their engagement in practice in terms of the identity they are developing" (p. 155). The mathematical tasks that CMLWs and MLWs engaged in were a way of determining the mathematical knowledge and understanding of number concepts they constructed in Flagway, how that knowledge varied among them, how participation in training influenced that knowledge, and, conversely, how that knowledge influenced participation in training.

As discussed earlier, the CMLWs and MLWs operated at two levels of engagement in Flagway training. As a result of these differences in engagement, the understanding that developed about the categorization of numbers used in Flagway looked vastly different. The CMLWs developed a very strong number sense because they saw themselves in the work and invested time in understanding the mathematics on a deeper level. In the CMLWs' learning, there was constant reflection about their past schooling and their prior mathematical knowledge, which helped them to negotiate the meaning of the number concepts and the categorization schemes used in Flagway. For both Naomi and DeMarcus, as their investment in understanding the work grew, so did their understanding of Flagway and their identities as CMLWs. For example, Naomi recalled moments of clarity she had about prime numbers (one in particular, that all counting numbers are made up of combinations of prime numbers). She was also able to articulate her thinking in regards to small primes and large primes and her problem in decomposing numbers made up of large primes. Naomi indicated that she was not sure if she had prior knowledge of this problem, but knew that she never articulated it before. Because of these moments of clarity in her formulation of trajectories, she came to understand the significance of prime numbers, which helped to inform her practice during training. As a result, in the training Naomi facilitated activities in which MLWs would have to work hard to understand prime numbers.

DeMarcus used Flagway as a way of reacquainting himself with number concepts from his past schooling that had grown unfamiliar. He created outbound trajectories (Wenger, 1998) when he saw the student he once was in some of the MLWs he worked with, frustrated and often unwilling to fully engage in the mathematics. When DeMarcus decided to familiarize himself with the mathematics in Flagway, he devoted himself to developing a deeper understanding of number concepts. He took a past mathematical self that he was not comfortable with and transformed that self into one who was confident and had an intellectual curiosity about mathematics, which substantially influenced his learning. This transformation is evidenced by DeMarcus's becoming an increasingly confident doer of mathematics. He used prime factorization strategies that he developed to help him determine how to decompose numbers into prime factors. He was also able to articulate his thinking in regard to how his concept of multiplication had shifted and demonstrated that shift several times when given a number to factor.

Unlike the CMLWs, the MLWs demonstrated a mundane and sometimes inadequate understanding of the number concepts in Flagway. Although learning of Flagway took place, they were unable to correctly categorize numbers into appropriate color categories and had difficulty identifying prime numbers. The level at which the CMLWs had engaged in Flagway, drawing upon their prior experiences, was not evident in either Charlene or Phil. In this sense, although Charlene and Phil were full participants of the Flagway training by every other account, they did not develop a deep understanding of the Flagway Game. This result is consistent with the observation by Nasir (2002) who suggests, "Development occurs both at an individual level and at the level of the practice itself" (p. 237). Because the MLWs were not the primary facilitators in Flagway training, this could be why peripheral trajectories were formed. Charlene and Phil were still in many respects developing their own understanding of prime numbers and the number categorization process. Zazkis and Campbell (1996b), contend that decomposing a number into its prime factorization is a nontrivial task that requires some prior knowledge and experience expressing composite numbers as products of prime factors. If these concepts are inadequately developed, then one may have some difficulty with these conceptualizations. Lave and Wenger (1991) also point out, "In many learning contexts, even quite narrowly defined, participants may disengage before attaining mastery over core skills" (p. 19). If the MLWs' level of participation evolved in the YPP and in training, so might their understanding of prime numbers, the categorization, and the identities they constructed.

Mathematics Literacy for Liberation and Liberation in Mathematics Literacy

In light of less and more recent research that has examined the underachievement and limited persistence of African American students in mathematics, the accumulation of these findings has created masternarratives (Giroux, Lankshear, McLaren, & Peters, 1996) of failure that marginalize and portray African Americans students as passive when it comes to their education (Perry, 2003), mathematics achievement, absent of agency and voice (Martin, 2007). Masternarratives fail to highlight acts of empowerment by African American students, particularly in urban settings like Chicago, who have worked to achieve mathematics literacy, not just for themselves, but also for others in their community through out-of-school student-led initiatives, like the YPP. Further, these masternarratives fail to show that African American students do in fact understand that the work of acquiring mathematics literacy is an act of liberation in itself, for personal fulfillment and for citizenship.

The participants in this study demonstrated persistence in working towards mathematics literacy in education. None of the participants had a mathematics concentration in school, but they chose to engage in an afterschool initiative centered on mathematics because they understood the urgency in their community for this kind of work. The MLWs spent 12 hours in school each day, including their stay for Flagway training – which further demonstrated their commitment and persistence.

Charlene and Phil made several errors as they engaged in mathematical tasks to categorize numbers. From one perspective, we can say that they did not have a strong understanding of mathematics. But we can also see that these two high school students were willing to challenge the notion that young people like themselves were not willing to grapple with mathematical concepts, no matter the difficulty. Surely, the mathematics used in the Flagway Game includes elementary mathematics concepts. It does, however, require considerable analysis, theory building, and understanding to explain the categorization of numbers. Although the MLWs did not have the categorization scheme completely figured out for all numbers, their engagement challenges a dominant discourse that suggests Black students do not necessarily explore mathematics beyond school contexts for intellectual purposes and for enjoyment.

Naomi and DeMarcus provided examples of counternarratives in their respective case studies where they demonstrated how they combat dominant discourses through their participation in YPP. Naomi possessed a rather strong mathematics identity and believed that possessing mathematics literacy would improve an individual's life chances. She reaped the benefits first hand by doing well in mathematics and gave examples of this from her prior schooling when she spoke of the prize she was awarded for winning a mathematics competition. Naomi also spoke with conviction about the importance of a collective community not standing on the sidelines while young people in Chicago continued to do poorly in education in general and mathematics in particular. Naomi reaffirmed that in a broader community in Chicago, minority and low-income communities do not always get access to quality education and it was up to all stakeholders to ensure that education is a right for all. As a result, her efforts in YPP attempted to mitigate these effects through her work with youth. Another way in which Naomi helped to create a counternarrative of agency was when she described how the YPP's work in the community aided in circumventing violence by creating knowledge and power. In some respects, the way in which Naomi embraced the YPP mission when she suggested that one of the goals of the YPP was to "push people to their full human potential," sent a broader message that from a community level, she invested in the collective responsibility to help young people do well in school because anything less is unacceptable.

As DeMarcus reflected on his past schooling, he realized that he had experienced inequities. He attributed these inequities to poor preparation in his self-proclaimed less-than-adequate educational background and study skills as compared to his classmates in college. DeMarcus referred to these inequities in his prior schooling as injustices. Although there was little in the present to change DeMarcus's schooling experience from his early years, he did express a commitment to strive for social equality along with improving the lives and the achievement potential of kids who had a schooling background similar to his. This commitment was also shown when DeMarcus recounted his inability to do mathematics. DeMarcus in many respects developed a negative mathematics identity and did not invest his energy in doing mathematics, because, as he stated, did not think that he was able to perform well in mathematics in comparison to his peers. But with DeMarcus's work in YPP and in Flagway training, in many respects he reinvested his energy in doing mathematics not only for himself but also for the young people he worked with. The accounts DeMarcus shared that are illustrated in his case study demonstrated a more positive mathematics identity over time. As Martin (2007) points out, the ability to do mathematics is only one facet of someone's life. A mathematics identity does not develop on its own, separate from other important identities people make for themselves. As a consequence of our experiences, all of our identities, taken together, manifest in new and different ways. The accounts of schooling that DeMarcus shared, primarily about mathematics, provided one example of a young person who gave up on a specific aspect of his academic life only to reclaim it when he found new purpose, new agency in himself, and new ways of acting to make a difference. His own struggle to understand the mathematics of the Flagway Game demonstrates his perseverance to perform well in mathematics for personal achievement.

Conclusion

The results of this study suggest that student-led initiatives like YPP Chicago show great promise for building mathematics literacy and developing identities in young people within CoPs. YPP also provides a different context where the mathematics education reform movement can be actualized. It is not top-down like many reform efforts, but bottom-up; created for young people by young people. Young people not only engage in mathematics in the YPP but they also build a social awareness of problems that exist within their communities and engage in work to help change it. Because of the reflective nature of the work mathematics literacy workers participate in, the YPP provides a space for young people to build social skills that enable them to gain a stronger sense of who they are and who they hope to become through prolonged engagement with others. By participating in a CoP like the YPP, students learn what it means to explore mathematics and become mathematically literate in their community and in a broader context.

This study suggested that students need prolonged engagement with seemingly simple mathematical concepts so that they can develop deep understanding for themselves. Prolonged engagement in mathematics can improve one’s confidence and willingness to do mathematics over time. Students must understand that correctness is not the only thing that is sought after when one engages in mathematics. Mathematics also requires deep thinking and a constant revision of ideas and what one thinks is correct or incorrect. Seemingly simple mathematical concepts should be explored intensely and over time.

Developing number concepts is a gradual process that may be challenging at times. One thing that the data revealed particularly with the high school mathematics literacy workers was the notion of articulation of mathematics in your own way and on your own terms. To learn and create identities as Wenger (1998) discusses, there is significant reflection, internalization, and interaction occurring as one engages in a social context. By wrestling with mathematics activities and making sense of the Flagway Game, in many respects, the CMLWs and MLWs were constantly negotiating what they understood, what they thought they understood, and what they did not understand. They were continuously making accommodations in their own practice (through engagement) and with their own way of knowing (through alignment and in the creation of trajectories). This is a subtle process that is not always explicit. As Lave and Wenger (1991) point out, "Changing membership in communities of practice, like participation, can be neither fully internalized nor fully externalized" (p. 54). The MLWs did not have a clear idea of prime numbers and where certain numbers should go in the color categories. But they were encouraged to at least try to think critically about the numbers. Our attention should not be focused completely on the errors made by these participants or their lack of understanding of some numbers concepts over others. Instead, we should consider that these students were willing to go beyond a basic understanding of what they already knew. Although the MLWs had difficulty doing the categorization activities, their learning was an emergent process. Further, as the CMLWs and MLWs engaged in this process of inquiry, they did learn more about themselves, which is another important aspect of the work of mathematics literacy worker. Furthermore, the

CMLWs and MLWs were willing to engage in the discovery aspect of mathematics, which is one of the main goals of YPP and the Flagway initiative.

Implications for Future Practice

Although part of this study focused on CMLWs' and MLWs' mathematics strategies and understanding of numbers used in the Flagway Game, implications for practice reach far beyond the game. This study underscored several important aspects of practice not only at the student level, but at the teacher level as well. The work of YPP Chicago in many ways necessitates a more intimate relationship between schools, students, and teachers to improve what and how students learn mathematics. As discussed in chapter 2, there is an emerging area of research that focuses on the importance of hearing the voice of students in school reform (Rudduck, 2007). I have also suggested this inclusion in various aspects of mathematics education reform. There are various ways teachers can be more involved in out-of-school and after school initiatives to bridge what students learn in school with what they learn outside of school. For example, teachers at participating schools that have the YPP could work more closely with the program to help CMLWs refine curriculum to meet the needs of the MLWs they serve. This work has begun in Chicago. The Office of Mathematics and Science (OMS) in Chicago Public Schools has established a partnership with YPP Chicago to work with additional "high need" schools. There are a number of teacher leaders involved with YPP Chicago who are also working in (and with) universities to prepare elementary pre-service teachers to do this kind of mathematics literacy work.

As the message of mathematics literacy is underscored in the broader YPP programming and organizational mission, teachers in mathematics classrooms should emphasize the importance of this message so that this point is more cohesive for all students. Teachers could also modify their mathematics pedagogy by tying mathematics into other important everyday contexts that students can relate to. Rudduck (2007) asked students what would improve teaching and learning for them, and many emphasized the importance of teachers connecting what they were learning "to their everyday lives or future jobs" (p. 591). Moreover, the study also revealed that students enjoyed a variety of activities, where they were not doing "too much writing and copying" (p. 591). Students also highlighted the importance of social clustering where they were "able to work collaboratively and have discussions" (p. 592) with others. There are a number of resources available to assist teachers in infusing these types of activities into their mathematics practice so that students can make more real world connections that affect them, the mathematics can be more engaging, and the students can take more interest when engaging in it (Gutstein & Peterson, 2005).

Implications for Future Research

Although in existence for more than 10 years, the Young People's Project is an underresearched area in mathematics education that deserves further attention. For this study, one of the major findings was that there were some very distinct identities that the CMLWs and MLWs constructed and those identities influenced the understanding of mathematics that they had. The study revealed very interesting connections that each participant made to the Young People's Project and their work in Flagway training and the broader community. Another important point that this study revealed was the complexity of identity formation within certain contexts and how it can change depending on the level of participation and the length of time spent in engagement. Because there were some very telling differences in the data between the CMLWs and the MLWs, further research studies is needed to reveal why there were distinct differences in their practice. Because this study was conducted over a 6-week period, longitudinal studies are needed that would provide longer contact time with participants. Furthermore, studies are needed:

1. To investigate CMLWs and MLWs in contexts in addition to Flagway trainings (e.g., during outreach, while they are playing the Flagway Game in tournaments with other sites, and while they are participating at planning retreats). There are multiple contexts where mathematics literacy workers engage in their work.
2. To investigate separately how CMLWs and MLWs develop their understanding of specific mathematical content over time while doing community outreach work. This topic is of particular interest to me because of the number of years CMLWs and MLWs can spend within the Young People's Project and the changing nature of their participation during the time they are there.
3. To investigate the effect that Flagway has had on elementary school students' learning through interaction with CMLWs and MLWs. Because of the current demand for evidence-based research, particularly with intervention programs like YPP, it is important to get an understanding of the influence this after-school student-led initiative has had on elementary students mathematics outcomes.
4. To study how engagement in curriculum development influences identity construction.
5. To conduct comparative studies with other organizations that are similar in to YPP (if any exist) by investigating similarities and differences in how they conduct mathematics literacy initiatives and to understand practices that best allow students opportunities for prolonged engagement in mathematics to improve their learning.

Implications for Future Theory Building

I am in accord with scholars like Martin (2007), Berry (2008), and Stinson (2004) who have argued for a reorientation of the research on African American students to highlight successes rather than failure in mathematics achievement. I further this notion by suggesting more research on Black students who have been disenfranchised historically and choose to persist in mathematics, in school, and in alternative settings to obtain mathematics literacy. This is a shift, in some respects, from research that primarily focuses on student assessment data and that make comparisons between groups of students, based on their achievement in mathematics on assessments. There should also be a reexamination of some of the frameworks that are used to theorize how mathematics achievement is viewed.

CRT and CoPs are relatively new areas of study in education in general and mathematics education in particular. Much has been learned through the deployment of these theories, in the field of education. But there still needs to be a continued analysis in mathematics education to examine the experiences of Black students in alternative community learning spaces, like YPP, and how these spaces influence learning, achievement in mathematics, and how it impacts student voice. Building on our knowledge of CRT and CoPs, can help to further an understanding of how students engage in mathematical practice and what contexts for mathematical practice are effective for developing mathematics literacy and doing mathematics literacy work. Further, research on CoPs is framed from the perspective of teachers existing in community learning spaces, but students negotiate these spaces as well. Drawing on theories like CRT and CoPs may also provide an opportunity to develop new theoretical frameworks to explain what happens in these learning contexts from the perspective of students. I believe this is fruitful area of research in uncovering student agency, voice, and mathematics learning.

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APPENDICES

APPENDIX A

FLAGWAY GAME OUTPUT FOR NUMBERS 2 THROUGH 100

Number	**Prime Factorization**	**Algebraic Form**	**Color Output**
2	2	A	RED
3	3	A	RED
4	2^2	A^2	YELLOW
5	5	A	RED
6	2×3	AB	BLUE
7	7	A	RED
8	2^3	A^3	YELLOW
9	3^2	A^2	YELLOW
10	2×5	AB	BLUE
11	11	A	RED
12	$2^2×3$	A^2B	YELLOW
13	13	A	RED
14	2×7	AB	BLUE
15	3×5	AB	BLUE
16	4^2	A^2	YELLOW
17	17	A	RED
18	$3^2×2$	A^2B	YELLOW
19	19	A	RED
20	$2^2×5$	A^2B	YELLOW
21	3×7	AB	BLUE
22	2×11	AB	BLUE
23	23	A	RED
24	$2^3×3$	A^3B	YELLOW
25	5^2	A^2	YELLOW
26	2×13	AB	BLUE
27	3^3	A^3	YELLOW
28	$2^2×7$	A^2B	YELLOW
29	29	A	RED
30	2×3×5	ABC	RED
31	31	A	RED
32	2^5	A^5	YELLOW
33	3×11	AB	BLUE
34	2×17	AB	BLUE
35	5×7	AB	BLUE
36	6^2	A^2	YELLOW
37	37	A	RED
38	2×19	AB	BLUE
39	3×13	AB	BLUE

Number	Prime Factorization	Algebraic Form	Color Output
40	$2^3 \times 5$	A^3B	YELLOW
41	41	A	RED
42	$2 \times 3 \times 7$	ABC	RED
43	43	A	RED
44	$2^2 \times 11$	A^2B	YELLOW
45	5×3^2	A^2B	YELLOW
46	2×23	AB	BLUE
47	47	A	RED
48	$2^4 \times 3$	A^4B	YELLOW
49	7^2	A^2	YELLOW
50	2×5^2	AB^2	YELLOW
51	51	A	RED
52	$2^2 \times 13$	A^2B	YELLOW
53	53	A	RED
54	2×17	AB	BLUE
55	5×11	AB	BLUE
56	$2^2 \times 14$	A^2B	YELLOW
57	$2^3 \times 7$	A^3B	YELLOW
58	2×29	AB	BLUE
59	59	A	RED
60	$2^2 \times 3 \times 5$	A^2BC	YELLOW
61	61	A	RED
62	2×31	AB	BLUE
63	$3^2 \times 7$	A^2B	YELLOW
64	2^6	A^6	YELLOW
65	5×13	AB	BLUE
66	$2 \times 3 \times 11$	ABC	RED
67	67	A	RED
68	$2^2 \times 17$	A^2B	YELLOW
69	3×23	AB	BLUE
70	$2 \times 5 \times 7$	ABC	RED
71	71	A	RED
72	2×6^2	A^2B	YELLOW
73	73	A	RED
74	2×37	AB	BLUE
75	3×5^2	A^2B	YELLOW
76	$2^2 \times 19$	A^2B	YELLOW
77	7×11	AB	BLUE
78	$2 \times 3 \times 13$	ABC	RED
79	79	A	RED
80	$2^4 \times 5$	A^4B	YELLOW
81	3^4	A^4	YELLOW
82	2×41	AB	BLUE
83	83	A	RED

Number	Prime Factorization	Algebraic Form	Color Output
84	$2^2 \times 3 \times 7$	A^2BC	YELLOW
85	5×17	AB	BLUE
86	2×43	AB	BLUE
87	87	A	RED
88	$2^3 \times 11$	A^3B	YELLOW
89	89	A	RED
90	$3^2 \times 2 \times 5$	A^2BC	YELLOW
91	91	A	RED
92	$2^2 \times 23$	A^2B	YELLOW
93	93	A	RED
94	2×47	AB	BLUE
95	5×19	AB	BLUE
96	$2^5 \times 3$	A^5B	YELLOW
97	97	A	RED
98	2×7^2	AB^2	YELLOW
99	$3^2 \times 11$	A^2B	YELLOW
100	$2^2 \times 5^2$	A^2B^2	YELLOW

APPENDIX B

YPP CHICAGO SURVEY

YPP Site Name: ____

Your Grade Level Grade: ____

Personal Experience
Please select the answer that best describes your experience.

1. How do you feel about your high school mathematics experience?

Very comfortable	Somewhat comfortable	Neither anxious nor comfortable	Somewhat anxious	Very anxious

2. How well do you like mathematics?

I love it	I like it	I feel neutral	I dislike it	I hate it

3. What mathematics classes have you taken or are you currently taking in high school?

____

____

____

____

4. How successful are you in your math classes?

Usually successful	More successful than not	Successful about half the time	More unsuccessful than not	Usually successful

5. How successful are/were you in Algebra?

Usually successful	More successful than not	Successful about half the time	More unsuccessful than not	Usually successful

6. To what extent do you know the work of the Algebra Project?

I am very familiar with the work of the Algebra Project	I am moderately familiar with the work of the Algebra Project	I am somewhat familiar with the work of the Algebra Project	I know very little about the work of the Algebra Project	I know nothing about the Algebra Project

Please write your answer in the space provided.

7. How many years have you been a Mathematics Literacy Worker for the Young People's Project?

____

____

8. List three reasons why you became a Mathematics Literacy Worker for the Young People's Project?

   a. ____

   b. ____

   c. ____

9. What do you see as the significance in your work as a Mathematics Literacy Worker in the Young People's Project?

____

____

____

10. Have you experienced an increase in your own learning of mathematics as a result of your involvement in the Young People's Project as a Mathematics Literacy Worker? In what way? Please explain.

____

____

____

11. How comfortable are you in designing and implementing a mathematical experience for the mathematics students that you work with? (For example: National Flagway Campaign)

____

____

____

____

12. Do you have any additional comments that you would like to share about your experience with the Young People's Project? Please put in the space provided.

____

____

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I would like your permission to contact you to participate in a study on the Mathematics Literacy Workers of the Young People's Project.

Would you like to participate in the study? Check ONE of the following:

YES, I will participate in the study ________

NO, I decline to participate in the study _______

If YES, Please give the following information:

Name: ____

Phone: ____

E-mail Address: ____

APPENDIX C

INTERVIEW PROTOCOL ONE FOR MATHEMATICS LITERACY WORKERS FOR YPP STUDY

1. Let us start out by talking about you. Tell me a little about yourself as a student.

2. How would you describe your educational background as it relates to mathematics?

    a. What would you say is your overall view of mathematics?

3. How did you become familiar with the Young People's Project?

    a. What led you to become part of this organization?

4. I am now going to read the YPP mission statement to you:

    "The mission of the Young People's Project is to use mathematics literacy as a tool to develop young leaders and organizers who radically change the quality of education and life in their communities so that all children have the opportunity to reach their full human potential."

    I want you to take a minute to think about this mission statement. Tell me what it means to you.

5. How would you describe mathematics literacy?

    a. How do you see yourself executing the goal of mathematics literacy in the Young People's Project?

6. How would you describe your role as a mathematics literacy worker in the Young People's Project?

    a. How would you describe your overall purpose as a mathematics literacy worker in the Young People's Project?
    (*This question is directed at the impact on Chicago communities)*

7. What have been some of the most memorable experiences you have had as a mathematics literacy worker in Young People's Project?

a. As it relates to the mathematics, mathematics games, Flagway, etc?

8.

a. I want you to think about your work in YPP last semester as compared to your work this semester. *(It could be production team, and the rest of them, the work with students).* Describe for me that experience.

b. What have been some lessons that you have taken away with you from that experience?

9. For Naomi and DeMarcus: Let's talk a little bit about planning and the materials that you use in MLW training:

   a. What are some of your overall objectives when you plan for your work with MLWs?

   b. Is working towards mathematics literacy at the top of the list?

   c. If not, then what is at the top of the list?

APPENDIX D

INTERVIEW PROTOCOL TWO FOR MATHEMATICS LITERACY WORKERS FOR YPP STUDY

In this particular protocol, I am trying to get at my participants' understanding of number used in the Flagway Game. I also want my participants to do some final reflection on the training, themselves, and their growth in the process. The protocol will be divided into two sets of questions, enacted questions and reflection questions.

Mathematical Tasks:

Let's talk a little about the Flagway game. I want you to think about the activities we have been doing with the numbers 2 through 50. According to Flagway, all numbers correspond to a color, Red, Yellow, and Blue.

a. 1 - Let's consider the first twenty numbers 2 through 21. Can you list these numbers for me and next to them the colors they correspond to? Explain your reasoning.

b. 2 - Can you repeat this for the numbers 35 through 50? Explain your reasoning here.

c. 3 - Can you write the algebraic form for each of these numbers? Explain your reasoning here.

    1) What theories have you developed about the numbers 2 – 50 as it relates to the categories Red, Yellow, and Blue? Explain your reasoning here.

Reflection Questions:

2. In doing these mathematical tasks with the numbers 2 – 50, how does this help you to think about these numbers?

    a. In what ways do these mathematical tasks help you to think about numbers in general?

    b. In what ways have these activities help you to think about numbers in different ways?

3. In thinking about what you have learned with numbers and the Flagway game during the course of the training, what parts of the mathematics seems challenging to you in communicating to young people when your are in outreach sites?

    a. What parts of the mathematics seem comfortable for you to communicate to children in the outreach sites?

    b. What would you say are YOUR mathematical goals with the Flagway game and understanding the numbers?

    c. What previous experiences have you had in mathematics that influence or shape these mathematical goals?

4. The training sessions have been organized with very specific components, Team Builders, Practice Day activities, and Debriefings.

    a. How have the Team Builders been useful to you in thinking about the work we have been doing?

    b. How have the Practice Day activities been useful to you in thinking about the work we have been doing?

    c. How have the Debriefing sessions been useful to you in thinking about the work we have been doing?

5. In thinking about the work that you have been doing these last few weeks, what does it mean to crack the code?

    a. Have you been able to crack the code?

6. As we wrap up training, describe some of the challenges that you still have about the mathematics? About the work overall?

    a. Describe some things that you feel very comfortable doing with the mathematics? And the work overall?

APPENDIX E

SAMPLE CODING TABLE: WITHIN-CASE ANALYSIS

Code	ID	Q#	Turn#	Interview Data	Notes
11100	103	3a	28.	So, I guess that's how **I became part of the community.**	She describes her work in YPP as being part of a community
10200	103	3a	29.	And then I thought you know after each session, I thought oh I'm not gonna come back, but then I kept thinking oh well I am running this program, this is me, ***I can change it, I can affect it, I can make it better, I can hire*** different people, ***I can figure out what I need to do, I can keep going and going and going.***	***Level of Engagement:*** Modes of belonging. It seems like her imagination kicked in. The possibilities beyond what is currently happening. If she becomes part of the organization then she can help to transform it in some way - **Agency**
10600	103	3a	30.	I don't want to just leave in the middle of our campaign, in the middle of us trying to figure out the curriculum so.	
11100	103	3a	31.	I think that's how **I became part of the community.**	Says it again talks about YPP as a community
	DNBC103	3a	32.	*DNBC: So why do you say, there is negative energy around YPP, what kind of energy is there? 7:56*	
10100	103	3a	33.	N: Well this is how I was introduced to YPP, I am working with five groups of high school students who are MLWs for YPP through Mind Rap. So all I know is that once a week, I spend two hours with YPP students trying to teach them Mind Rap. Their coming in like this, "man where's my pay check, dudda dudda. I didn't get paid on-time, you know it's boring, like just saying negative things about the Young People's Project." I'm thinking how dare they, you know not pay these students, all this stuff. Uhm, and then when I talk to Naa about like working for the program over the summer, I wanted to make sure it was, I wanted to hear it from a teacher's position, as opposed to the students. So I asked her, you know what was going on and then she explained to me that uhm,	Based on her conversation with Naa, Naomi demonstrates the importance of commitment to this work.
10100	103	3a	34.	it's very time consuming and No you know, you don't get your paycheck on time, you sort of you have to have a second job or a third job to, it's not the kind of job that you are going to have to make a living, it's not going to sustain you. She like told me straight up and she said because of that, uhm, because of	Despite the obvious challenges of being a part of an organization that does not sustain its workers

APPENDIX F

SAMPLE CODING TABLE: CROSS-CASE ANALYSIS

Code	ID	Q#	Turn#	Interview Data	Notes
10710	102	7	1.	And, and they had got very offended with that and so after that, they came to us and asked us for help. We both, all of us was leaders, if they needed help, we gave them help, and if I needed help, they gave us help. So, that's my memorable moments.	Identity transformation in practice Saw himself at a leader: Increasingly confident doer of mathematics
10710	104	6	*1.*	And something and that's actually something that the Young People's Project helping me to understand is how even as complex or far fetched a connection between math and probably my regular my everyday life is that there is an actual connection and it is just up to me to eventually find that connection. And of course I'm going to be the only one that draws that connection to myself, but YPP and the people that I work with are serving as guides for me to reach that understanding.	The realization that you are capable of drawing mathematical connections for yourself Increasingly confident doer of mathematics
10710	104	3c	1.	D: Let's see, I would say let's see, I would say uhm the biggest influence is, I could, being like I consider myself a person not too good at math. And I consider myself a person unwilling to do math. Uhm, for a large portion of my life. I feel as though in that respect, I can relate a lot to the kids that I work with. And I felt as though, this was able to have this affect on me, then it would be possible for it, the kids that I work with to have this affect. So, I guess one of the bigger influences on me is knowing this is possible. Uhm, and like just judging by the fact that this reinvigorated my willingness to do math, I would hope that that somehow it would be able to reinvigorate their willingness to do math. Uhm, and again like, probably it's based on the level of learning that I, where I'm at right now. I love what it is that I'm doing. This is fun to me to you know do this stuff. So, my influence in that respect would be to do the same thing for these kids.	His disposition towards mathematics changes over time. Increasingly confident doer of mathematics
10720	101	2	*1.*	C: Well ***math has always been fun for me***. Uhm, ***because I love it so much. It's not that it's easy, it's just like it's fun.*** And ***<u>like when I do it, it becomes easy because I make it fun</u>*** but uhm, as being a sophomore it's getting a little hard, but at the same time I try to make a fun because I love math.	Sees math as fun Confident doer of mathematics
10720	103	2	1.	I really think like I enjoy math and I like doing math and I love discovering it and I love figuring stuff out.	Confident doer of mathematics
10720	103	2	1.	It's like so prevalent for minorities to be skilled in that area because it allows them to excel in, it opens a lot of doors, like if I hadn't won that competition, I got a two thousand dollar scholarship, I got a laptop, I got just so many doors, so many opportunities, just for, you know, my math skills. And so, it's really important. 3:17	Confident doer of mathematics Probably she felt that when she won it reaffirmed something in her mind about her ability to do mathematics.

APPENDIX G

CODING SCHEMES

10000 – Identities

- 10100 – One Who Perseveres and Committed to Mathematics Literacy Work
- 10200 – Agent of Change
- 10300 – An Authority in Flagway Trainings
- 10400 – Role Model in Flagway Trainings
- 10500 – Supporter of Others
- 10600 – One with a Sense of Responsibility
- 10700 – Doers of Mathematics
    - 10710 – Increasingly Confident Doers of Mathematics
    - 10720 – Confident Doers of Mathematics
        - 10721 – Mathematics Identity
        - 10722 – Passion for Learning Mathematics

11000 – Identity Transformation in Practice –
(Some realization has been made by the person about himself or herself)

11500 – Imagination in Identity

12000 – Understanding of Numbers in the Flagway Game

- 12100 – Memorization
- 12200 – Color Association
- 12300 – Flexibility with Numbers
    - 12310 – Prime Factorization of Numbers
    - 12320 – Prime Factorization Strategy of Participants
    - 12330 – Using Division Rules
        - 12331 – The Use of Low Primes and High Primes
    - 12340 – Definition of Prime Numbers
    - 12350 – Quickness with Numbers
    - 12360 – Number and Color Association