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Cultivating Mathematics Identities In and Out of School and In Between

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In recent years, researchers have explored the question of literacy development both within and outside of school (Hill & Vasudevan, 2007; Mahiri, 2004; Morrell, 2007). Many have focused on specific cultural practices that contribute to literacy acquisition and development. In addition, they have considered the notion of these sites and places as *spaces* (Lefebvre, 1974; Soja, 1989) in which literacy is developed and an identity related to one's literacy experiences is acquired. These spaces encompass more than a physical location; they include "social and cultural ideas of place, the meaning humans attribute to place, and the cultural and social knowledge surrounding various locations" (Cole, 2009, p. 22). In thinking about these directions in literacy research and how "literate persons" are developed through their backgrounds, experiences, and practices both within and outside of schools, it is worth thinking about the analogous question of how a "mathematical person" is developed. It is important to consider how people's mathematics identities might be cultivated in spaces within schools, outside of schools, and in spaces in-between, and how these experiences might contribute to the development of a mathematical identity as well as the development and dissemination of mathematical knowledge.

Although some who have focused on the acquisition of mathematical knowledge have used out-of-school contexts to engage students in mathematics learning within schools (Bonnoto, 2005; Moses & Cobb, 2001), others have demonstrated that both functional and rigorous mathematics can be done by those using methods obtained outside of school (Saxe, 1991). Further, researchers have also explored how mathematical conceptual understanding might be supported and developed out of school: for example, Nasir (2000) explored how African American young men used percent and ratio when choosing players for their basketball teams. Several have suggested that "mathematics learning and practice in and out of school can build on and complement each other" (Masingila, Davidenko, & Prus-Wisniowska, 1996, p. 177), and that formal and informal mathematics learning should not be experienced in schools or outside of schools as completely discrete entities (Schoenfeld, 1991). The mathematics backgrounds, knowledge, and experiences that students bring with them to school can be effectively used to

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develop mathematics understanding and knowledge and serve to engage students (Bonnoto, 2005).

It has been shown that these out-of-school contexts for enacting mathematics practices are informed by students' cultural backgrounds and experiences (Saxe, 1991). Cobb and Hodge (2002), Martin (2000), Nasir and Saxe (2003) and others have attended to the role that culture, context, and community play in mathematics learning for young people. A broader discussion of cultural practices (Gutiérrez & Rogoff, 2003; Nasir & Saxe, 2003) that positively affect mathematics learning, practice, and socialization *outside of school*, particularly for young people of color in the United States, would be useful for developing in-school practices that support mathematics engagement as well as for creating intentional out-of-school spaces that do the same. For example, literacy educators and education researchers have begun to develop and explore literacy spaces outside of school that are sites for induction into literacy communities and contribute in intentional ways to individual and group socialization around literacy (e.g., Kinloch, 2005). Further, elements of these practices are used in informal and formal school settings. Despite the compelling research exploring the role of culture and context in mathematics learning, we do not do enough to create meaningful spaces within cultural contexts for mathematics practice for young people outside of school (the Young People's Project, which seeks to promote mathematics literacy among young people participating in The Algebra Project, founded by Robert [Bob] Moses, is an exception), nor do we do enough to build on the mathematics experiences that they do have outside of school.

What remains underexplored in mathematics education research is how the mathematically talented in the United States are socialized to do mathematics outside of school—how do they develop their mathematics skills, interests, and dispositions? In the past, I have explored the mathematical experiences of high achieving high school students and the networks that foster their mathematics success (Walker, 2006). Most recently, I have been conducting a study of African American mathematicians, exploring their formative, educational, and professional experiences in mathematics (Walker, 2009, 2011). What has emerged as a key factor in the success of high achievers and mathematicians alike is the important role that out-of-school experiences and relationships, many rooted in specific cultural and social contexts, have played in their mathematics knowledge development and socialization.

In this article, I discuss the mathematical spaces that mathematicians describe as important to their success. I identify mathematical spaces as sites where mathematics knowledge is developed, where induction into a particular community of mathematics doers occurs, and where relationships or interactions contribute to the development of a mathematics identity. These spaces may be physical locations like a school or classroom or locations to which the individual attaches a

particular social, cultural, or mathematical meaning due to interactions and experiences she or he had there. Here I focus on those mathematical spaces experienced by mathematicians during childhood and adolescence, with the goal of contributing to our thinking about how we might engage adolescents in mathematics, particularly those from underrepresented groups. In the conclusion, I suggest that we move from these sometimes "inadvertent" spaces that foster development for individuals to creating and examining "intentional" spaces that contribute in strong ways to mathematics socialization and talent development for larger groups, particularly for underserved students. Efforts to craft purposeful mathematical spaces, I argue, should reflect the bridging of out-of-school and in-school networks, relationships, and practices.

Research Context

In a previous study exploring "academic communities" (interpersonal networks that supported mathematics success) of high achieving Black and Latina/o students at an urban public high school, it became apparent that these students were doing mathematics in various ways in spaces within school, outside of school, and in-between (Walker, 2006). I began to wonder what kinds of mathematical spaces were experienced and created by mathematicians, arguably the highest achievers, and for Black mathematicians specifically. What might we learn from their narratives about doing mathematics in and out of school? Like many researchers, I suggest that engagement should be considered as a construct that simultaneously encompasses behavior, emotion, and cognition (Fredricks, Blumenfeld, & Paris, 2004). As Fredricks, Blumenfeld, and Paris (2004) describe:

> Behavioral engagement draws on the idea of participation; it includes involvement in academic and social or extracurricular activities and is considered crucial for achieving positive academic outcomes and preventing dropping out. Emotional engagement encompasses positive and negative reactions to teachers, classmates, academics, and school and is presumed to create ties to an institution and influence willingness to do the work. Finally, cognitive engagement draws on the idea of investment; it incorporates thoughtfulness and willingness to exert the effort necessary to comprehend complex ideas and master difficult skills. (p. 60)

Considering these three components of engagement simultaneously allows us to deeply understand young people's attitudes and actions around mathematics and develop a fuller picture of their mathematics identities and the socialization process that aids them in seeing themselves as doers of mathematics. While studies of mathematicians often describe their experiences in graduate school and within the profession (e.g., Burton, 2004; Herzig, 2004) and some research addresses the early socialization experiences of mathematicians, these studies do not critically examine the spaces in which these early socialization experiences

occur. I argue that, for Black mathematicians in particular, the locations that facilitate engagement are weighted with important historical, social, and cultural overtones that, for some, may be unique to their experiences as Blacks pursuing mathematical excellence.

Related to these ideas about where mathematics is taking place is the notion of how those doing mathematics see themselves and are seen. The notion that one's mathematical identity might have to be reconciled with one's core identity—be it ethnic, gender, or otherwise—has also gained prominence in the literature (Boaler & Greeno, 2000; Nasir & Saxe, 2003). Some of the research relating to ethnic identity and academic achievement suggests that students of color must negotiate multiple identities, at times compromising their ethnic identity in order to fully embrace their academic identity (e.g., Fordham & Ogbu, 1986). Others have suggested that these identities overlap in positive ways (e.g., Flores-Gonzalez, 1999; Horvat & Lewis, 2003). Largely missing from these discussions, however, is how one's mathematical identity might be formed and developed—and evolve—over time. In asking mathematicians about their formative experiences, I hope to contribute to our understanding of how one's mathematics identity might shift and evolve over time, and how these shifts are related to one's experiences within mathematical spaces.

A particularly interesting facet of in-school learning versus out-of-school learning is the usual characterization of in-school learning as being focused on individual cognition, while out-of-school learning is seen as developed via shared cognition (Resnick, 1987; Masingila, Davidenko, & Prus-Wisniowska, 1996). This "shared cognition" lends itself to Martin's (2000) formulation of identity and socialization being informed by community and interpersonal contexts. This study seeks to address these issues through an examination of the questions below:

1. What experiences contribute to mathematicians' positive mathematics identity development and socialization? Where do these experiences occur?
2. What are key characteristics of spaces that facilitate mathematics identity development and socialization?

Method

The data presented here come from a larger ongoing study of African American mathematicians. The participants in this study are 27 African American mathematicians, all of whom were born in the United States, and whose PhDs in mathematics or a mathematical science were granted between 1941 and 2008. This is a purposeful sample; participants were identified using resources including the website created and developed by Dr. Scott Williams (himself a Black mathematician), *Mathematicians of the African Diaspora* (http://math.buffalo.edu/mad), as well as the text *Black Mathematicians and Their Works* (Newell, Gipson, Rich,

& Stubblefield, 1980), published in 1980. In addition, once the initial pool of subjects was identified, snowball sampling (by which participants identified other mathematicians) was used to augment the sample.

Table 1
Characteristics of the Sample of Black Mathematicians

	Male	*Female*
PhDs 1940s–1970s	6	1
PhDs 1970s–1990s	7	2
PhDs 1990s–2000s	8	3
Total	21	6

Interviews were conducted using a semi-structured, open-ended interview protocol developed by me, and lasted between 45 minutes and 3 hours. Most interviews lasted at least an hour. The interview questions focused on mathematicians' early experiences with mathematics, in and out of school, as well as their later educational and professional experiences. Interviews were recorded, transcribed, and coded by a research assistant and myself. We first coded interviews broadly for early episodes and experiences where a mathematician was describing doing or learning about mathematics. Within these narratives, we examined the texts for incidences in childhood and adolescence that related to mathematics learning and categorized those as occurring within school (within or outside of the mathematics classroom) or outside of school (within some academic setting or not). After this initial coding, we examined these narratives within and across locations (in-school, out-of-school, and in-between spaces) for themes relating to aspects of mathematics identity and socialization, focusing on engagement (emotional, behavioral, and cognitive aspects) as well as racial, social, historical, and cultural themes relating to mathematics. After exploring these narratives for common as well as conflicting themes, I then purposefully selected 6 representative vignettes from 4 mathematicians' narratives to describe and explore spaces in which mathematical identities are cultivated, both inside and outside of school, during childhood and adolescence. All mathematicians have been identified using pseudonyms.

Two of the mathematicians, Eleanor Gladwell (PhD 1970s) and Wayne Leverett (PhD 1960s), came of age in the 1950s, attended rural segregated schools in the South, were undergraduates at historically Black colleges and universities, and were among the first African Americans to integrate their previously all-White graduate institutions. One, Nathaniel Long (PhD 1980s), grew up in a multiracial, working class, urban neighborhood in the North and attended a predominantly White college and graduate school in the North. The remaining mathematician, Craig Thomas, earned his PhD in the 1990s. He attended predominantly

Black elementary and secondary schools in a Southern city, and attended a historically Black college and predominantly White graduate school for the PhD.

"Here It Was in Action": Cultivating Mathematics Identity in Out-of-school Spaces

In Vignette 1, Nathaniel Long talks about his experiences growing up in a multiracial working class neighborhood in a Northern industrial city:

> I grew up in a—well, call it Little Italy—a mostly Italian and some Irish and German, but all Catholic [neighborhood]. And then there were a smattering of Black families. My mother actually grew up [on the block] the generation before, so they all knew each other. It was very close-knit. One of the kids, Henry, was about five years older than me and he would play ball with us younger kids…I would play chess with him, and he started giving me these little puzzles. He would give me little problems to work on, little brain teasers and that sort of thing, which I was able to solve.
>
> Henry was very interested in mathematics. He ended up majoring in mathematics and became a math teacher at a secondary school. At any rate, I think Henry Fletcher [*pseudonym*] was a very profound influence. Even when we played sports, it was always correctness. A lot of kids just want to win, and there was always a sense of winning by the rules. It would be second or third down, and we would carefully reconstruct what had happened to make sure that we had the down right. He would go examine the sideline to make sure the ball was not out of bounds. There was always this sort of rigor to what actually happened. "Were you tagged before? Where was the ball when you were tagged? Were you beyond the pole or not beyond the pole?" At any rate, I think that was a very positive influence on me in my early to late teens.

Nathaniel Long's framing of his neighborhood as one that supported intellectual engagement seems to contradict much of what has been popularly described about the lack of support for educational activities in predominantly Black settings. Long's description helps to develop a "counterweight corpus of scholarship" (Morris, 2004, p. 72) that challenges this notion (Anderson, 1988; Hilliard, 2003; Morris, 2004; Perry, 2003). In his narrative, Long is careful to construct his experiences within the context of a "world within a world" that was predominantly Black, describes the role of the "atmosphere" in contributing to intellectual development, and uses mathematical language to describe even the ways in which he and his peers played street football—down to the "rigor" of play and rules for use in determining outcomes. Prominent in this narrative is the importance of one person, Henry Fletcher, an older peer who began "giving [Long] these little puzzles" to solve. Fletcher's later becoming a mathematics teacher could almost have been predicted by Long's story.

Other mathematicians in the sample, like Long, described the importance of older peers (siblings and cousins as well as classmates and friends) in creating

environments that supported mathematics learning and engagement. These experiences took place at home, in school, on playgrounds, and in other settings. A few younger mathematicians, particularly those who lived in predominantly Black neighborhoods and attended predominantly White schools, noted that they had a range of experiences with their "school friends" and "neighborhood friends". They "just played" with their neighborhood friends and tended to have academic interactions with their "school friends".

In Vignette 2, Wayne Leverett describes two key mathematics experiences that occurred outside of school and his realization that mathematics was a viable career option:

> One thing I remember is when I was in about the ninth grade, my uncle worked for a construction company. He saw the foreman using a slide rule. He just got curious about it, so the foreman said, "Well, next time I place an order for equipment, I will order you one if you'd like." So the slide rule came with a thick manual about trigonometric functions and those such things. It was way over my uncle's head. He was a carpenter. On the GI bill he got trained to do carpentry. In the family, people thought that I was some sort of bookworm because I was always reading books. So he just gave it to me. I wanted to get to the basics of the thing. I wanted to understand it, so I actually read the manual. I knew enough algebra and trigonometry to figure out most of the scales. For me it became a hobby.
>
> One day, a good buddy of mine and I were idling time away walking down a country road headed home. We came upon a little White man who was surveying some land. He needed two strong fellows to help him pull some chains. He told us that he would pay us $.75 per hour to do this. This is a lot more than you could make working on the farm. You could earn two or three dollars a day by working on the farm, but here is a guy who is going to pay $.75 per hour. I thought that this was an enormous sum of money to pull these chains… When this guy started talking to us, he had a transit. He would set it up and sight through here and swing around through a certain angle and sight through there. He could compute the distance between two far away points. When he found out that I knew a little trigonometry, he started teaching me how to use this transit. He was so impressed with me and I was so amazed by how much money you could make using this trigonometry. So I said right away that I wanted to be an engineer because I thought that engineers made even more money than high school math teachers. I wanted to be a civil engineer.
>
> So this was a moving experience. I wish that students at the tenth grade level could see something like this, where "here is something I am learning in school that is being used to earn money." Meeting that engineer who was surveying land... he was friendly enough to teach me things about how he was actually measuring the distance, and in doing this without having to jump across that ditch over there to get to. Now we had studied about triangles and all—if you know this side and you know this side and you know the angle between you can get the length of the third side and all that. But here it was in action. This was very powerful.

Embedded throughout Wayne Leverett's interview are references to the importance of his family in facilitating his learning. Another uncle marched him to a college registrar's office and informed the registrar that Leverett was a top student and should therefore be admitted to that particular college. He was. At that college, Leverett benefited from a strong mathematics program. Leverett—as described later in Vignette 5—also describes the very important role of his high school teachers in his mathematics development. But in this vignette, Leverett describes how two critical experiences with mathematics—both outside of school—contributed to his understanding of mathematics, and further, how mathematics was done in the real world. Further, Leverett expresses a wish that secondary school students could have this kind of real-world experience, where they can see the usefulness and importance of the mathematics they are learning in school to real problems in the world outside of school. His career—in private industry and as an academic—reflects these early experiences.

Several mathematicians of all ages speak to the importance of mathematics exposure outside of school, whether or not it was rooted in real-world contexts. One mathematician recalled she and her siblings embarking on home improvement projects with their father that related to mathematics; another described an experience attending a lecture in high school that discussed the still unsolved problems in mathematics that piqued his interest, and helped him to realize that mathematics was not "just a toolkit." Craig Thomas' experience with his grandfather below echoes these points.

In Vignette 3, Craig Thomas describes a mathematical experience he had with his grandfather in a southern city:

> My grandfather lived right around the corner from here [the College where Thomas is now a professor]. I remember he would always have these mental challenges that he would give me all the time…I actually use one of them in particular [when I'm teaching]. We were on the front porch and he was asking me—he was saying, if he walked halfway to the end of the porch, and then halfway again, and then halfway again, and so on, how many steps would it take him to reach the end of the porch? And so, I may have guessed five or something, I don't know. So then he actually proceeded to do it, halfway, and then halfway, and then halfway, but the idea was that he was converging—he didn't use the term convergence, but he never actually reached it—but he got closer and closer and closer, and of course he didn't say within epsilon…
>
> But anyway, I have fun when I'm teaching about convergence to really tap into it at this early level. One just because I have fun telling the story—but also to give my students an idea of the sorts of things they can do with their students, because some of them may go on to become teachers, or just with their grandchildren one day, whatever the case may be. These are the sorts of things that can really bring high level things in very early and just challenge the mind and make you think.

This experience is so vivid in Thomas's memory that he shares it with students in his classes. He recognizes that this story is about more than mathematics: in sharing it, Thomas underscores the importance of passing along mathematical ideas, that mathematics doesn't just happen in school, and that his students can use accessible examples of mathematics when interacting with their own students or family members to illuminate complex mathematical ideas.

These three vignettes reveal that, for these mathematicians, opportunities to engage in mathematics occurred within very disparate experiences that were all rooted in cultural contexts. For Long, the peer culture that had developed in his neighborhood, perhaps as an offshoot of the close relationships among the mothers, supported intellectual pursuits within multiple contexts—promoting adherence to rigorous rules while playing sports but also engaging in games and puzzles. For Leverett, his uncle's curiosity and recognition that Leverett could benefit from a book with trigonometric formulas, and further, the convergence of key events—his school learning, his own out-of-school book learning, and a chance meeting with someone who used mathematics in his career—all contributed to Leverett's understanding that there was more to do in life than work as a farm laborer, which was the most visible career opportunity for African Americans in the rural South in the 1950s and 1960s. For Thomas, the opportunity that his grandfather gave him to think about mathematics in a deep way while lounging on a porch one afternoon—not just focusing on drills and number sense, but in thinking about some complex mathematical concepts—has, according to him, had an impact on how he thinks about his own teaching and mathematical development.

What is notable about all three vignettes is that these experiences contributed to the development of the three mathematicians' mathematical selves. Further, the people involved in these vignettes who have a great deal to do with how these mathematicians think about their early experiences with mathematics range from close family members (Thomas's grandfather and Leverett's uncle), to peers (Long's "mentor"), to individuals that are never seen or heard from again (Leverett's surveyor). Within these out-of-school spaces—a porch, a field, a neighborhood street—there were opportunities to learn mathematics, to develop rigorous mathematical thinking, and to learn habits of mind that contributed to these mathematicians' development.

"That Was It: I Could Do Math": Cultivating Mathematics Identity Within Schools

Many successful adults can point to the critical role of teachers in their lives, and every mathematician that has participated in the larger study points to key experiences and relationships with dynamic and charismatic "teachers" both within and outside of school as being integral to their success. These teachers

might have been peers as in the case of Nathaniel Long, traditional school-teachers, or out-of-school adults like Craig Thomas's grandfather, who were instrumental to these mathematicians' development. But in this section I focus on in-school experiences, and how classroom teachers crafted mathematical spaces that were meaningful to these mathematicians. Eleanor Gladwell illustrates in Vignette 4 how school relationships have an impact on one's mathematics identity and describes the power of learning beyond the typical and traditional classroom teaching/learning dynamic:

> I had a high school math teacher who was a younger man that was recently out of college, so that means he had lots of energy and enthusiasm about mathematics. And that was about the time of Sputnik. So they had all these institutes around the country to try to increase interest in math, and they had a lot of teacher's institutes. And so he would go to those.
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> I think it's because of him that I really excelled in math in high school. For example, when I got to trigonometry, the county would not allow them to teach trigonometry because there were not enough students—you had to have enough for a big class. Well, he only had five, six, or eight, you know. So he decided that we needed trigonometry to go to college. So he agreed that if our parents would bring us back in the evenings, he would teach trigonometry. And they did. That's how we learned, that's how we got our trig.
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> When Mr. Holly said I could do math, that was it, I could do math. So I never thought that was strange at all. And the high school teachers, they all told us we could do whatever we wanted to, you know. So in a school with mostly Black teachers, you got the message that you just needed to work hard and you could do whatever you wanted to do.

What is notable about this story is Mr. Holly's commitment to ensuring, despite policy constraints, that students he felt could benefit from having extra mathematics would get it-even outside of school hours. In addition, it underscores the parents' commitment (Siddle Walker, 1996) to helping their children get the education they needed during an era of rigid racial segregation. Like Long, Gladwell talks about the importance of the community in supporting intellectual endeavors—in this case the parents of the students making sure that they were able to take advantage of Mr. Holly's after school instruction. But Gladwell goes on to talk about the larger cultural context of her experience: the educational leaders that small, southern, predominantly Black towns and communities have created.

In addition, Gladwell's telling of this story about Mr. Holly reveals something about her mathematics identity. In a field where much of the discourse about women in the field focuses on their supposed lack of self efficacy, Gladwell talks about how growing up in a segregated era posed clear challenges related to her race and gender. But she also describes how teachers who believed in her and demonstrated that belief in tangible ways, made her believe in herself and her

mathematical talent, too. It was, therefore, not at all "strange" that she did well in mathematics.

Many mathematicians also describe teachers (of mathematics as well as of other subjects) who ensured that students were exposed to extracurricular mathematics opportunities outside of school—through enrichment programs, after-school or before-school clubs, or summer activities.

In Vignette 5, Wayne Leverett continues his narrative, building on his story about the surveyor and the slide rule to one about the importance of his secondary school teachers in his mathematical development:

> But this slide rule was one of my first memories about experiences that got me hooked on math for sure. At school when the teachers discovered that I could use this thing, they were quite amazed. I remember maybe in the tenth grade algebra class, she [the teacher] gave me half the class [to teach]. My first memory of doing math [in school] was as a show off. I was having fun, but I think the fact that the teachers gave me praise really encouraged me to do a bit more. When we were taking algebra, Mrs. Barr gave me a college algebra book because I think she feared that I could keep up with the regular algebra easily. She gave me a college algebra book and would check off a couple of problems and say, "See if you can do these tonight." I would go home determined to do them because I wanted to stay in her good graces. She thought I was smarter than I was and I wanted to keep it that way. So I would work on the problems, sometimes, half the night before I would figure out how to solve them, but I would come in the next day as if I had solved them in 15 minutes. "Here is the solution, give me some more." I managed to keep that going until I graduated…[A]t the end of the year when I tried to return the book, she said, "Wayne, you keep that book. It will do you more good than it will do me." I thought it was such a great treasure to have her book.
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> There was another math teacher at school who did pretty much the same thing, except that he collected his books back at the end of the year. His name was Mr. Barr. I do feel that I had some sort of special treatment that at least two teachers at a very small school noticed that I had some abilities and they did it on their own. They didn't get extra pay, but they were essentially giving me after school tutoring. Nobody, not even the principal, [knew] that these things were going on. So I never have enough praise for those two teachers.
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> The only thing that I have taken to everywhere I go is to remember what teachers did for me when I was in high school. Because if Burgess had ignored me, or if Barr had ignored me, or [his college mathematics professor], I don't know where I would be today. I certainly wouldn't be here. So when I see a student who has some ability and is trying, I always try to pull them aside and do something special. I keep looking for students to befriend and yes, I try to find a good student to mentor and watch them and see how they grow.

Both Gladwell and Leverett talk about these particular high school experiences without mentioning much about the other students who were in their classes. But teachers are not the only actors within schools who have an influence on students.

In Vignette 6, Craig Thomas talks about his peers and the supportive culture for his mathematics work at his high school:

> One thing I often remember: I was in 8th grade, I believe, and I was on a little local television show, a little game show. And the thing I remember about this, I [made it to the final round], and if I had gotten my [last] question right, I would have won.
>
> I remember getting to school the next day and I remember Ladonna Rogers [a pseudonym], she was one of those who would just make your life miserable. She was loud, she was just one of those who would make life hard, just because she could. And I remember I was so stunned—Ladonna Rogers came up to me and said, "We were rooting for you! I said, he's in my homeroom!" I was so stunned—she liked to take digs at everybody and me, especially, and she's up here rooting for me because I'm in her homeroom. And I remember that sticking out in my memory, that she was proud of me, I guess, or something, and that I guess I could infer from other experiences that there was more of that than I realized [at the time].

As Thomas' vignette 6 describes, the multiple roles of peers—in childhood and adolescence, but also continuing in adulthood—is a theme in many mathematicians' interviews. Some mathematicians describe separate peer groups for academic and social pursuits, others describe close knit peer groups that had a strong academic as well as social focus. Peers, in many cases, are key sources of mathematics instruction and inspiration. As one mathematician revealed, his older classmate's admonitions were rooted in the social context of the school, which had been recently desegregated:

> He said, "Look, you have a responsibility." I still remember to this day he says, "You're better than any of us in terms of doing this stuff." And he says, "You're probably better that most of the White students." He says, "You got to stay number one, and you also have an obligation to help, you know, to tutor and stuff like that." So you know, anybody that was kind of interested I would help them. Not because of him, I would have done that anyway. But I did feel this obligation because he would monitor what I was doing….He told me that that was my obligation, and I kind of believed him. There were times when I kind of didn't feel like studying, I would kind of like hear his voice. Which was really kind of interesting to me. And I wouldn't remember his name or his face if he would walk up to me now at all. In a way I would like to thank him.

However, Gladwell, Leverett, and Thomas's experiences also speak to the importance of mathematics teachers going beyond the prescribed curriculum to engage students' mathematical interests and potential. In all three vignettes, as Gladwell says, there is a "message"—"you just needed to work hard and you could do whatever you wanted to do"—about mathematics that is being sent to Gladwell, Leverett, Thomas and their fellow students. In Gladwell's and Leverett's case, this message is directly rooted in the historical context of segregated schooling in the South. To counter this, Gladwell's teacher enlisted the communi-

ty's aid in preparing students for college mathematics and Leverett's teachers gave him a very strong message about their beliefs in his ability, establishing him as co-teacher and giving him college-level work. Thomas's teachers, in an era where school segregation was unlawful but still present, sent a message not just to Thomas, but to his peers: that his mathematical project is important enough to be presented to fellow students during instructional time. All of these teachers are using modes of instruction and induction into mathematical practice that are occurring inside as well as outside of the traditional mathematics classroom space.

Spaces In Between: Building Bridges Across Multiple Worlds, Modes, and Identities

These six vignettes reveal that spaces and identities are not necessarily discrete. In-school and out-of-school spaces overlap, and the participants within these spaces take on different roles. For example, Leverett's learning of trigonometry took place in several settings and through several modalities: through his uncle, who gave him a slide rule manual with trigonometric functions; through school, where he learned mathematics in his classroom and from his teachers' out-of-school tutoring; and through the surveyor, who gave him practical experience but also reinforced mathematics content Leverett had learned and fostered Leverett's understanding of possibilities of careers using mathematics. In addition, Leverett in Vignette 5 serves as student and apprentice teacher in his mathematics classroom, as does Thomas in Vignette 6 in his mathematics class and other classes. Although Gladwell's trigonometry class occurred as a traditional teacher-students mathematics class arrangement, it occurred after school, when parents, teacher, and students all had to make special arrangements to participate. All of these characteristics facilitated mathematics learning and socialization within school, outside of school, and in "in-between" spaces. There was formal and informal mathematics learning, as well as important experiences that occurred outside of school that contributed to knowledge and understanding of school mathematics concepts.

Second, several vignettes echo previous findings in a study with high achieving high school students (Walker, 2006) that show that persons and relationships from multiple worlds formed academic communities (comprising family members, peers, teachers, and others) who had an important impact on the mathematicians' development. In addition, as I discovered in the high achievers study, the persons providing support or socialization opportunities for the mathematicians are not necessarily themselves mathematics teachers or mathematicians. In fact, some of these persons are those who would be considered "uneducated", or "undereducated", in the formal sense by many.

Third, the importance of opportunity in contribution to mathematics socialization for these mathematicians is key. Much has been made of the concept of "opportunity to learn" and specifically, opportunity to learn rigorous mathematics. However, as I define the concept here, this idea is not limited to within school opportunities to learn, but opportunities in and outside of school that are both presented to and sought by mathematicians as adolescents. The mathematicians in this study—and the four whose vignettes are presented here—describe multiple opportunities and contexts in which to learn mathematics. Mathematics learning occurred both outside of school (in family settings, with friends, through random interactions), within school (in mathematics classrooms, through school projects), and in in-between spaces (after school sessions and informal mathematics teaching and learning spaces in school buildings).

Conclusion

These narratives suggest that we can be much more successful in improving mathematics outcomes and fostering interest in mathematics by rethinking how and where mathematics learning and practice occur, and where one's mathematics identity is developed. To do this, this study of mathematicians suggests that we should build on out-of-school spaces that support mathematics socialization and also re-imagine the mathematics classroom to be a space that not only provides opportunities to learn meaningful mathematics, but supports mathematics identity development and positive socialization experiences.

But we also have to think about how we insure that meaningful mathematics occurs beyond fleeting conversations, students' individual experiences, and the spaces in which they happen to find themselves. Our expectations of students' abilities are key—if we think students have potential and if they are worthy of our attention in spaces that support mathematics learning, we become much more intentional and purposeful about creating these spaces. This is true in all four mathematicians' vignettes—whether it is teachers, peers, or relatives contributing to early mathematics development. Thus, opportunities to engage in meaningful mathematics have to have intentionality and purpose, and should not solely be haphazard or happenstance. For too many of our students, particularly our underserved Black and Latino/a students, these opportunities are limited.

Evidence shows that for Black and Latino/a high school students attending urban schools, even those with strong mathematics identities and positive socialization experiences, opportunities to learn mathematics may not be equivalent to those at other schools serving predominantly White students. Opportunities to take advanced level mathematics classes, for example, are not equal across affluent and poor schools. Elsewhere, I have written about how schools might maximize opportunity for underrepresented high school students (Walker, 2007b) sug-

gesting that schools do the following to foster opportunity and belongingness: expand our thinking about who can do mathematics, build on students' existing academic communities, learn from schools (particularly college and university programs) that promote mathematics excellence for underrepresented students, expand the options in school mathematics courses and enrichment opportunities, and reduce underrepresented students' isolation in advanced mathematics settings.

Experiences that promote mathematics socialization, identity development, and learning are critically important, because in the lives of Black mathematicians they have resonance. To wit, within these mathematical spaces, there are experiences that mathematicians had as young people that continue to resonate with them years later. These experiences contribute not only to their own construction of self as a mathematics doer, but also to their knowledge of mathematics content. Further, these past experiences can contribute to how they think about their own practice as mathematicians. For example, Thomas's experience with his grandfather on the porch "shows up" in his classes when he is teaching the concept of convergence; Leverett shares his surveyor experience as an example of "mathematics in action". Gladwell is renowned as a mentor to young mathematicians, and her experience with Mr. Holly may influence how she conceives of her work mentoring graduate students. In a program she has co-developed, the emphasis is on giving participants a "head start" on graduate level work, in much the same way Mr. Holly ensured that she and her peers would be prepared for college work.

What appears to contribute greatly to a mathematical space's resonance is the presence of key individuals and/or relationships. In all of these experiences, whether described by mathematicians or high achieving high school students, it is not just the space—the neighborhood, the school, the classroom—but it is also the significant relationships and experiences with family members, peers, teachers, mentors, and others in these spaces that are remembered. These relationships and experiences, built on high expectations, contribute to these individuals' practices, and the larger practices, of the mathematical communities to which they belong (Walker, 2007a, 2012). Much of the research describing factors that contribute to the high achievement of underserved students in mathematics, in particular, points to the importance of relationships that are both personal and relate to the content (Berry, 2008; Moore, 2006).

The process of crafting intentional spaces, rather than allowing for (or hoping for the possibility of) inadvertent spaces, in which young people learn and practice mathematics, develop a strong mathematics identity, and are inducted into a community of mathematics doers, I argue, must attend to these issues of opportunity and resonance. Interviews with Black mathematicians reveal that early on there were strong influences on their mathematical development and how they think about mathematics both inside and outside of school. What was surprising was that both out-of-school experiences and in-school experiences appear

to be influential to talent and identity development, and at times, out-of-school experiences, however fleeting, had a seemingly lasting impact on Black mathematicians' conceptions of self, mathematics, and their mathematics ability. With these ideas in mind, schools can provide spaces for students that ensure that they feel that they rightfully belong to a community of mathematics doers, that they have opportunities to engage in meaningful mathematics, and that their experiences in these spaces are resonant and contribute to the development of their identities as mathematical persons.

At the Symposium

During the symposium, I presented work from a study of Black American high achievers—high school students and mathematicians—focusing on key mathematical spaces that fostered their mathematics excellence. During the discussion, we discussed links between mathematical spaces and young people's mathematics engagement, identities, and socialization, and how experiences in these spaces serve as counternarratives to the dominant discourse about high mathematics achievement that ignores mathematics excellence among underserved students. We had the opportunity to brainstorm about ways that schools, communities, and neighborhoods could develop formal and informal spaces that support mathematics learning, and discussed how more research in these settings could facilitate better understanding of how to improve mathematics teaching and learning for Black students in particular.

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