Pathways and Pipeline and the Growing Pains of Creating a Computer Science Pathway
for a Majority-Minority District

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Practitioners and Scholars interested in developing computer science (CS) pathways must understand the nuance lives and goals students encounter when navigating the tricky lessons of life. For many watchers of the STEM field, the underrepresentation of women and minorities serves to fortify our society’s opinion and imagination of what or who is a scientist and the risk of creating processes that fail to “tease out” ethnic minorities and women’s experiences within the larger STEM field (Alfred, Ray, & Johnson, 2019). The following research article explores four high school students’ experience with computer science programming in the Milwaukee Public School system in three focal areas (Supporting Student Imaginings, Building a solid foundation of identity and Student Scaffolding, Mentorship, and Support). The students describe how their desires, fears, family, and dreams affected how they arrived at their computer science program and how it drives their burgeoning computer science identity. Moreover, this research yielded a new framework (1) Early student opportunities, 2) Awareness of Critical Educational Junctures, 3) Building Healthy CS Identities, and 4) Celebrating, Encouraging Success and Wins. We consider that this framework could be beneficial when thinking about healthy and productive computer science pathways that target underrepresented persons within the STEM field.

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I. Introduction

For some time now, there has been a concern that the United States does not produce sufficient numbers of students or workers trained in computer science (CS) fields to remain globally competitive (Sass, 2015). Of particular concern is the underrepresentation of women and ethnic minorities in Science, Technology, Engineering, or Mathematics (STEM) fields. For example, African Americans and Latinos made up around 27% of the overall United States workforce as of 2016; however, these two groups account for only 16% of those employed in a STEM occupation (Funk & Parker, 2018). When considering why this underrepresentation continues, past research has suggested that the field needs to pay greater attention to how Black and Latino workers are seeded and grown into STEM or, most importantly, computer science professions. Indeed, for many watchers of the fields inside STEM, this underrepresentation of women and minorities serves to fortify our society’s opinion and imagination of what or whom a scientist is. Moreover, these patterns of undisrupted negative views run the risk of reinforcing processes that fail to “tease out” ethnic minorities and women’s experiences within the larger STEM field (Alfred, Ray, & Johnson, 2019).

Although our quest for social justice in the United States is a long and winding road, onlookers of the STEM field—particularly within the area of computer science—find practices like early and intentional programming with minoritized groups and women as green shoots to progress (K–12 Computer Science Framework, 2016). Early opportunities from groups such as, “K–12 Computer Science Framework; Computing Machinery; Code.org; Computer Science Teachers Association; and Cyber Innovation Center” function as opportunities to begin shaping and cultivating a positive computer science identity. For example, Code.org’s theory of change is their belief in building a “full K-12 curriculum pathway” (Code.org, 2021) as an opportunity to
address diversity in K-12 computer science that ultimately serves to diversify the technology sector (Code.org, 2019). Similarly, programs like Exploring Computer Science (ECS) also consider their intentional focus on youth as an opportunity to build positive attitudes towards the technology sector within underrepresented populations.

Understanding why minoritized students enter into computer science pathways is imperative for researchers and educators interested in opening up the world of computational thinking as a new and innovative learning mode. Though many computer science groups, program operators, and agencies see the potential of computer science pathways to guide underrepresented students into computer science careers, we regard these pathways as new and needing further examination. The following research article explores four high school students experience with computer science programming in the Milwaukee Public School system. The students speak about how their desires, fears, family, and dreams all affected how they arrived at their computer science program and burgeoning computer scientist identity. Moreover, this research yielded a new framework categorized by four characteristics, 1) Early student opportunities, 2) Awareness of Critical Educational Junctures, 3) Celebrating, Encouraging Success, and Win, and 4) Building Healthy CS Identities. Moreover, we hope this new framework will supplement researchers’ and practitioners’ ideas of what a healthy CS Pathway consists of.

Project Partnership and Background
The study was conducted in Wisconsin, a midwestern state of the United States. Milwaukee Public School District (MPS), is the largest school district in the state of Wisconsin. MPS serves a student population of 77,746, with 88% of that population being from minoritized student populations.
Additionally, this research is in coordination with the Preparing the Urban Milwaukee for Pathways in Computer Science (PUMP-CS), an NSF grant that promotes equitable access to high-quality Computer Science education for all students in Wisconsin across grades K-12. Additionally, PUMP-CS is a collection of initiatives with the goal of ensuring that all Milwaukee Public Schools students have access to an equitable, meaningful, rigorous, and relevant inquiry-based Computer Science education. The Research-Practice Partnership (RPP) consists of The Learning Partnership, American Institute for Research, Marquette University, and Milwaukee Public School to assist MPS district leadership in developing healthy student CS identities through clearly defined CS pathways. Moreover, this partnership works with teachers and school administrators to provide high-quality professional training, curricula, and CS paths that further develop students’ computational thinking as an opportunity to improve educational and life outcomes.

II. Literature Review

The K-12 Computer Science Framework (2016), describes computational thinking as the thought processes involved in solving problems, particularly problems that can be expressed as steps or algorithms that a computer can carry out. For us, educators’ embrace of computational thinking models serves as an opportunity to realign the K-12 mission (i.e., Knowledge and Social Preparedness) better to meet the needs of our information age society. Indeed, this focus on a step-by-step praxis equips students with problem-solving skills that allow them to analyze, make inferences, and break problems down into manageable pieces (Thomas, 2021). In addition, the National Association of Colleges and Employers Job Outlook 2020 survey found that beyond a strong GPA, problem-solving skills and the ability to work as part of a team are the most crucial attributes employers seek when organizing their workplaces (NACE Staff, 2020). Taking the
notion of student preparedness (i.e., socialization) seriously requires districts to begin to think about how they can devise systems and curriculums that serve their students for their future.

For minority-majority districts, student pathways into fields like computer science require strategic thinking and planning if we are to see improvements in the number of underrepresented persons in STEM fields. Scholars, like Sims (2018), believe districts need to build out curriculums and practices that embrace their minoritized communities’ uniqueness (Sims, 2018). Indeed, Sims built upon the notion of “expectancy-value-cost” that seeks to understand why and how marginalized male students fail to develop interest and desire to enter fields defined by computational thinking. Based on the research of Eccles et al. (1983) pertaining to students’ choice of majors and careers, much of these choices depend on how much value students put in the field and their expectations that they will be successful. Eccles’ research has shown that students’ expectations of success are based on successful experiences with relevant school subjects over time. Students’ value in a particular field is influenced by their enjoyment of experiences in the field. With this knowledge, minority-majority districts interested in creating pathways for underrepresented persons in STEM fields must consider how their early opportunities forecast their students’ futures and opinions of STEM and its offshoots.

Early Computer Science Opportunities

Many of the short-term outreach opportunities used in districts before the systematic introduction of intentional CS pathways were intended to raise young students’ awareness of the computer science field (Nouri et al., 2020). Indeed for Abu-El-Haija & Payton (2019), these opportunities typically target K–12 students as a mechanism to encourage them into CS career paths. However, as CS careers and culture have become more prevalent within our society,
programming in primary and secondary schools has become more sophisticated and focused on concepts and practices from computational fields.

Studies have begun to unpack how early and continuous CS programs create pathways that orient students into the computer science field. Abu-El-Haija & Payton (2019) describe, these pathways as an opportunity to address the ethnic and gender disparities in the computer science field by highlighting the inequities in the field and crafting curricula that challenge its historical narratives of lack of interest. Brady et al. (2017) found when examining the program growth of Computational Thinking for Girls (CT4G), that the growth in enrollment in the CT4G workshop was in conjunction with attitudinal gains which suggests the power of providing multiple pathways into computing. The authors also found that the more the program was “made real or put into the student’s social context,” the better students began to understand what it would mean to be a computer scientist- which led to better-prepared students, and, most critically, a better-prepared student mindset and imagination ready to tackle their computational futures (Alfred, Ray, & Johnson, 2019).

Building CS Identities

For this article, we defined a healthy STEM identity as 1. Persons think of themselves as science learners and 2. develop an identity as someone who a) knows about, b) uses, and c) sometimes contributes to the field of science (The Center for the Advancement of Informal Science Education (2018)).

For many STEM and social science experts, the underrepresentation of minoritized groups and women also serves as an economic obstacle to social improvement within the larger society. Funk & Parker (2018), found that the representation of women, African Americans, and Hispanics hold economic issues or, as they termed it, “Pocketbook implications for workers.”
many cases, STEM jobs and careers have relatively higher incomes and flexibility than many non-STEM jobs, and denying access to these career paths places these underrepresented groups at a significant economic disadvantage. Moreover, Funk & Parker (2018) also noted that “One potential barrier for those wishing to enter the STEM workforce is the generally higher level of educational attainment required for such positions. Among college-educated workers, one-in-three (33%) majored in a STEM field (Funk & Parker 2018, p. 17).” The under-representation of women and minoritized groups in more lucrative engineering and computer science fields significantly add to the widening earnings disparity that has expanded over the last decade (Funk & Parker, 2018).

Carlone and Johnson (2007) maintained that students in structured STEM programs could engage in collaborative environments that allow for opportunities to be recognized by peers and faculty, which, in turn, allows them to identify as scientists. This key finding undergirds the importance of early and intentional CS pathways as an opportunity to build within students a love and interest in a CS future. For example, Oseguera et al. (2020), studying Hunter, Laursen, and Seymour (2007), “found that summer undergraduate involvement had shifted students’ attitudes to ‘becoming a scientist’ which made them more mindful of their role and engendered a sense of ownership toward the work they were engaged in” (p. 232).

Moreover, Carlone and Johnson (2007) found that being a part of a structured program connected to the STEM fields brings individuals with similar interests together, facilitating their identification with a scientific identity. For example, Espinosa (2011) found in her study of “Pipelines and Pathways” that minoritized students who consider science a vital aspect of their self-identity are more likely to persist in their STEM major. Conversely, scholars have asserted that students who are recognized by faculty as being “science people” are 1) more confident
about their academic abilities and 2) serves as a predictor of students remaining in STEM fields after their formal education period (Kaleva et al., 2019).

**Social Identity Formation**

Hogg & Abrams (1988), regard social identity theory is the idea that a person is knowingly aware that he or she belongs to a social category or group. A social group comprises individuals who hold a common social identification and view themselves as members of the same social grouping. Indeed, in “A Social Comparison Process,” persons who are similar to “the self” are categorized with the self and are labeled the in-group– persons who differ from the self are categorized as the out-group (Stets & Burke, 2000). Thus Hogg & Abrams (1988) theorize that there are two critical processes involved in social identity formation, 1) self-categorization and 2) social comparison, with both serving as design mechanisms, complicating and guiding a person’s identity down twin paths of conformity and uniqueness.

However, when looking at how students acquire a “Scientific Identity,” Herrera et al. (2012), theorized that it occurs in a person’s social adjustments and negotiations, similar to how Hogg & Adams (1988) describe traditional identity formation. Studying the relationship between a STEM identity and other psychosocial identities such as race, gender, and ethnicity shows that students redefine what it means to be a scientist and a person of color within a social group (Herrera et al, 2012). Researchers also found that marginalized populations need care paid to how program leaders engage notions of race, ethnicity, and gender, particularly how these leaders encourage students to enter fields of study that will put them at risk of being isolated (Herrera et al, 2012).

The significance of cultural and racial identity contributing to marginalized students’ psychosocial wellness has been well-documented and studied in Social Science and Education literature. Using a case study methodological approach, Lane (2016) found that while STEM
classes were hostile environments in which Black students felt they needed to prove their intelligence, intentionally designed undergraduate research programs provided a space in which they “could fully realize their intellectual selves as Black individuals (p. 165).” The level of identity activated (the personal or the social) depends on factors and situations. Thus, clearly and intentionally building programs that understand how and what moves students in a positive direction will help the field grapple with and improve how identity and marginalization could combine to build better pathways for underrepresented groups.

The relational aspect of identity is also connected to how students are guided into the field. Some, like Estrada, Hernandez, & Schultz (2018), might regard this professional guidance as a form of mentor-protégé understanding that they see in three crucial factors for mentees experiencing positive outcomes (Eby, et al., 2013).

I. “First, mentors can provide instrumental support, provided resources and opportunity to the protégé to engage in goal attainment (Kram, 1985), which can include ‘the specific mentor behaviors of providing task-related assistance, sponsorship, exposure and visibility, and coaching’” (Eby et al., 2013, p. 3).

II. Second, psychosocial support occurs when a mentor enhances “an individual’s sense of competence, identity, and effectiveness in a professional role” (Nakkula and Harris, 2013, p. 3)

III. Thirdly, relationship quality (sometimes referred to as “relationship satisfaction”) is an adequate assessment of liking, may include feelings of trust, empathy, respect, and connectedness (Nakkula and Harris, 2013, p. 3)”
IV. Methodology

Aim of the study
This study investigated how students and teachers understand their computer science program participation and what factors contribute to their decision to continue in an early STEM K-12 pathway.

Grounded Theory
The study approached the interviews using a descriptive qualitative design based on Glaser & Strauss’s (2008) grounded theory model. Grounded theory was used to give students and teachers a voice in how they perceive their participation in computer science programming. Saldaña (2009) regards the grounded theory process as focusing on multiple participant populations as a group instead of a single case (Alvesson and Sko¨ldberg, 1994). Humans are affected by the social world and require meaning to be continuously modified by experiences and interactions with others (Baker et al., 1992; Crooks, 2001). The grounded theory aims to generate theories by establishing different concepts from the data that have been collected. Those theories are then analyzed through social contexts in which they will later be applied (Glaser and Strauss, 1967).

Respondents
This study consisted of eight teachers or students participating in the MPS’s ECS or CSD computer science programming. The research team recruited interested teachers and emailed their classes to identify interested students. Four students between ages 13-17, were selected from our student solicitation. Student and teacher names are located in “Table 1: Student and Teacher Participants.”

Table 1: Student and Teacher Participants
The research sample consists of four students and four teachers participating in either ECS or CSD computer science programming in the Milwaukee Public School District.

Researchers used pseudonyms for student names.

<table>
<thead>
<tr>
<th>Student</th>
<th>Student Ethnicity and Gender</th>
<th>Student’s Corresponding Teacher</th>
<th>Teacher Ethnicity and Gender</th>
<th>Grade</th>
<th>Participating CS Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peter</td>
<td>Asian (Hmong), Male</td>
<td>Jenny Nickles</td>
<td>Euro American, Female</td>
<td>10th</td>
<td>Exploring Computer Science (ECS)</td>
</tr>
<tr>
<td>Mark</td>
<td>African American, Male</td>
<td>James Dawson</td>
<td>African American, Male</td>
<td>11th</td>
<td>Exploring Computer Science (ECS)</td>
</tr>
<tr>
<td>Mary</td>
<td>African American, Female</td>
<td>Janet Torres</td>
<td>Latina, Female</td>
<td>9th</td>
<td>Exploring Computer Science (ECS)</td>
</tr>
<tr>
<td>Abigail</td>
<td>Latina, Female</td>
<td>Janet Torres</td>
<td>Latina, Female</td>
<td>9th</td>
<td>Exploring Computer Science (ECS)</td>
</tr>
<tr>
<td>NA</td>
<td>NA</td>
<td>Kevin Potter</td>
<td>Euro-American, Male</td>
<td>11th</td>
<td>Exploring Computer Science (ECS)</td>
</tr>
</tbody>
</table>

**Research Site**

This research is in coordination with the Preparing the Urban Milwaukee for Pathways in Computer Science (PUMP-CS), an NSF grant that promotes equitable access to high-quality Computer Science education for all students in Wisconsin across grades K-12. Additionally, PUMP-CS is a collection of initiatives with the goal of ensure that all Milwaukee Public Schools students have access to an equitable, meaningful, rigorous, and relevant inquiry-based Computer Science education. The Research-Practice Partnership (RPP) consists of The Learning Partnership, American Institute for Research, Marquette University, and Milwaukee Public
School to assist MPS district leadership in developing healthy student CS identities through clearly defined CS pathways. Moreover, this partnership works with teachers and school administrators to provide high-quality professional training, curricula, and CS paths that further develop students’ computational thinking as an opportunity to improve educational and life outcomes.

**Exploring Computer Science (ECS)**
The following section is a description and overview of the Exploring Computer Science (ECS) program, the program study for this project.

Exploring Computer Science (ECS) is a K-12 national program (curriculum and professional development) committed to democratizing computer science knowledge by increasing learning opportunities for all students at the high school level, with a specific focus on access for traditionally underrepresented students. The ECS program consists of a high school preparatory computer science course combined with a professional development program for teachers. ECS is an outgrowth of research that focuses on disparities and access issues along racial and socioeconomic lines. This research was also detailed in the 2008 book *Stuck in the Shallow End* (Margolis et al., 2008).

The ECS curriculum consists of six units that are six weeks each, covering Human-Computer Interaction, Problem Solving, Web Design, Introduction to Programming, Computing and Data Analysis, and Robotics. ECS also offers two units that can be used as alternates to either unit 5 or 6, “E-Textiles”, and “Artificial Intelligence” (ECS, 2021). The ECS curriculum is designed to encourage student inquiry and equity-based instructional practices. All students, particularly those in schools with high numbers of low-income students and students of color, are introduced to the problem solving, computational practices, and modes of inquiry associated with
computer science. Moreover, the ECS curriculum is structured to align with college preparation coursework and Career and Technical Education pathways that include Information Technology; Engineering and Design; and Arts, Media, and Entertainment Technology (ECS, 2021).

**Data collection**
Data collection involved semi-structured interviews (Weiss 1995). All interviews were recorded using Zoom Video Communications due to the Milwaukee Public Schools COVID-19 closure. Automatic Sync Transcription services and the lead author performed interview transcription. The interviews lasted for an average of 30-45 minutes. The first author also conducted two impromptu meetings with MPS teachers after classroom visits. These meetings lasted 20-25 minutes and were conducted using Zoom Video Communication.

Each interview was opened with the question, “Why did you take a computer class? Followed by “How did you become interested in computers?” This allowed the participants to tell about their experiences in their own words. We also raised questions on specific computer science and pathway needs, educational and social content, and information participants might desire to help their continued involvement with MPS pathway work. Following each interview, field notes were taken. These included brief data on the participants interviewed and observations made during the interview or classroom visit. Data collection stopped when theoretical saturation was reached (Saldaña, 2009).

**Data analysis**
The research design used in this study was Corbin & Strauss’s (2008) grounded theory. This design aimed to understand how students and teachers regard educational programming created to provide what we regard as “early career” and educational training for students of color and women to enter the STEM fields. We converted codes into categories through a grounded theory process where we constantly compared to other codes and analytic memos. After completing
the coding phase, the researchers compared the major coding areas to literature and interview memos to conceptualize and create the Computer Science Pathway Framework.

Data from the interviews were analyzed and categorized according to the constant comparative method of data analysis (Corbin & Strauss, 2008). We collected data during the interviews, summarized it into different themes, and confirmed and modified it throughout the analyses. The data analysis started after the first interview and consisted of open, axial and selective coding. Open coding included repeated readings of the interviews and an in-depth, line-by-line analysis of the data. When a new concept or unknown idea was raised in an interview, we consulted literature to help with meaning-making and coding. Utilizing open coding, data were coded under various headings according to their content to open up data and consistently compare themes and categories that emerged from subsequent interviews (Saldaña, 2009). In the axial coding, categories were linked, with sub-categories describing the specific category. In the final selective coding, the categories were linked together, which resulted in a core category (Saldaña, 2009).

Coding Analysis
The research data informing this article comes from early research that found five beneficial categories necessary for students’ and teachers’ participation in a STEM pathway; 1) Early Student Opportunities, 2) Awareness of Critical Educational Junctures, 3) Celebrating, Encouraging Success, and Wins, 4) Building Healthy CS Identity, and 5) Student Relationships. Table 2 explains how an inductive coding process labeled each connection to a given category.

<table>
<thead>
<tr>
<th>Category Name</th>
<th>Category Description</th>
<th>Reason for Inclusion</th>
<th># of Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Student Opportunities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awareness of Critical Educational Junctures</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Celebrating, Encouraging Success, and Wins</td>
<td></td>
<td></td>
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<tr>
<td>Building Healthy CS Identity</td>
<td></td>
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<td></td>
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<tr>
<td>Student Relationships</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>Description</td>
<td>Text</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Early Student Opportunities</td>
<td>Instances of how early CS encounters encourage continued pathway participation.</td>
<td>We found that early student CS participation and skills development created a sense of student belonging and a healthy identity. Additionally, the research found that the earlier a student begins CS training, the more likely they will stay in a CS Pathway (Code.org; CSTA; ECE P Alliance, 2021).</td>
<td></td>
</tr>
<tr>
<td>Awareness of Critical Educational Junctures</td>
<td>Instances of building, teacher, and classroom changes and how these breaks in educational matriculation affected student and teacher opinion of CS participation.</td>
<td>Understanding teacher and student experiences with K-12 matriculation practices could help programmers understand where and when an intervention is needed.</td>
<td></td>
</tr>
<tr>
<td>Celebrating, Encouraging Success, and Win</td>
<td>Celebrating wins stimulates dopamine release in the brain, reinforcing the learning experience and strengthening a person’s sense of connectedness (Fogg, 2019).</td>
<td>Verbal encouragement and praise are the easiest ways to motivate and celebrate students—also building student-teacher connections.</td>
<td></td>
</tr>
<tr>
<td>Building Healthy CS Identity</td>
<td>Self-concept, personality development, and values are all closely related to identity formation (Herman, 2011).</td>
<td>They acknowledge students’ unique identities and how they effectively student social and educational participation rather than trying to be colorblind.</td>
<td></td>
</tr>
<tr>
<td>Student Relationships</td>
<td>Discussion on how educators work against norms that harm students and build relationships with students.</td>
<td>All efforts were in support of our students.</td>
<td></td>
</tr>
</tbody>
</table>
V. Findings

The following examines students and teachers participating in CS programming in Milwaukee Public Schools. Through this research, students and teachers describe what it was like to enter, teach and participate in a newly emerging CS pathway. The participants describe four areas that were important in their CS journey; these are; 1. Early student opportunities, 2. Awareness of Critical Educational Junctures, 3. Celebrating, Encouraging Success, and Win, and 4. Building Healthy CS Identities.

Additionally, this section explores race or ethnicity, students’ STEM post-secondary education, and career ambitions, mainly how these ambitions are developed based on students’ intrinsic interests and external experiences in mathematics and science course-taking as early as middle school (Maltese and Tai 2011; Tai et al. 2006). From our qualitative stories, our students showed interest in computer science early in life. Moreover, we found that students were fortunate to meet a teacher, participate in a computer science (CS) program, or have a visionary parent funneling them into a CS pathway. After an introduction to the CS framework we developed through student and teacher experiences and voices, we present the framework data through case study narratives and analysis.

Framing the Pathways Through Students’ Experiences (Milwaukee Public Schools and Characteristics of a CS Pathway)

Our participants believed early support and encouragement to enter STEM pathways were critical to building healthy CS identities—the belief that they are science learners and “someone who a) knows about, b) uses, and c) sometimes contributes to the field of science” (The Center for the Advancement of Informal Science Education, 2018). For the two young men of the study, their intrinsic values (from families and hands-on experience repairing electronic
devices) served as a driving force into a CS pathway and an opportunity to expand their interest in electronics repair. In contrast, the two young ladies were encouraged and pushed into the CS pathway by their mentor and teacher (i.e. extrinsic values). No matter how the students were funneled into CS programming, we know that for 3 out of 4, early encouragement and support served as the primary catalyst of their CS identity. We also found that teacher mentorship, care, and focus on student matriculation also pushed students into a STEM pathway.

Furthermore, we found these characteristics being described by the students as critical to how they develop positive attributes we believed encourage their participation in CS programming and identity formation. The research found four areas (1. Early student opportunities, 2. Awareness of Critical Educational Junctures, 3. Celebrating, Encouraging Success, and Win and 4. Building Healthy CS Identities) that students and teachers identified as crucial in their entrance, participation, and continuation in what we regard as an earlier k-12 computer science pathway. These four areas will be examined through a two-part design: a qualitative vignette followed by an examination of how students and teachers experience fit each framework area. Although this research is ongoing, we found these areas of significance as necessary characteristics to consider when developing CS pathways.

**Area 1: Early Opportunities through home and school**

Students’ ability to imagine themselves as a part of a field or a career path is a significant marker of their resilience to continue into college, specialized training, and careers (Perez-Felkner, 2015). For minoritized students, particularly those attending schools that do not have a tertiary educational tradition, the ability to imagine, ones future self, becomes an organizational and social problem that may exacerbate their readiness to transition to college and fields that require post-secondary specialized education. The students interviewed spoke to this notion,
particularly how their families, mentors, teachers, and community helped them imagine themselves as computer scientists.

### a. Peter’s Story

Peter, a Hmong immigrant student, started on his computer science path repairing computers in his home alongside his dad as part of a small repair business. During our interview, Peter spoke about his love of anime and his interest in things like coding and computer animation, stating, “my inspiration would be like anime. Like even though I’ve watched a lot of cartoons and stuff, it’s kind of like, it gives me motivation, you know, to maybe one day write cool stories.” Although Peter, an Asian male student, is a part of an over-represented group in computer animation, he stated that his teachers and family made clear that his love of anime could be cultivated and made real within the computer science field.

While working on computers with his dad, he imagined that computer repair was a possibility, but it was not until he encountered the Exploring Computer Science (ECS) program during his middle school years that he believed he could be a part of the CS fields at a higher level. His participation in programs like ECS, Technology Education and Literacy in Schools (TEALS), and Computer Science Discoveries ease him into things like coding, programming, and to an extent, gaming (although he claims his classmates are bigger gamers than he),

*I got to high school... I start being serious ... think about my future, I think about my career... it was hard at first, teachers would were helping me, I kind of felt this connection, you know? Like we could do anything together, you know? And that is kind of like -- is one of the things that make me like do more computing* [sic].

Peter (similar to Mark, the student featured in our next section) demonstrates how consistent early exposure to computer science programming can help students imagine themselves in the field of computer science. For example, Peter, just taking the first steps of making the transition
from a viewer of anime to a person who believes that they can create and write anime as a possible career, inspired him to continue with his CS training even when he found it difficult,

Like even though I watched a lot of cartoons and stuff, like, it gives me motivation, you know. I see what these people (people who work in the animation field) in these movies and stuff are doing with their life and I kind of think of myself, you know, what am I going to do with my life when I grow up? What should I do? What, should I make things and prepare for my future, you know? This has help me think about my future.

Peter’s family and the school’s encouragement, particularly his dad, were vital to him just entering a CS program and a larger CS pathway. However, similar to what Dou et al. (2020) found, without students having significant first-hand exposure to CS programming or experiences, young people are at risk of being persuaded by socially divergent stereotypes of computer scientists that have the possibility of persuading them away from CS fields.

Nevertheless, and most importantly, their teachers have prepared them to face the realities of a social milieu traditionally denied access to people in their social, racial, and economic classes. Moreover, the key to Dou et al. (2020), Peter, and other students you will meet later was how their teachers, through the student’s CS program participation, reset how the students understood the social dynamic of the computer science field. Through clear examinations of the racial dynamics, and the underrepresentation of minority peoples.

Table 3: Area 1: Early Opportunities through home and school

Area 2: Building a solid foundation of identity (into a CS Future)

Mark’s story is about teacher care and healthy identity formation as a driver of students into a CS pathway, notably how the mentorship of his teachers catalyzed the strengthening of his computer science self-conception. Nevertheless, during his interview, Mr. Dawson (a black male,
former technology professional) described how he focuses on underrepresented students in tech, like Mark, by encouraging them to “not only imagine themselves entering into STEM careers but to explore how the STEM field can improve our community.” Mr. Dawson, again a black male teacher and Mark's teacher, continued and spoke about how it was essential for him to build relationships with students based on genuine love and care for the student’s future. This localization of CS work is similar to what Sims (2018), found in his research on why black males failed to enter CS pathways. For Sim and Mr. Dawson, black students’ economic and social reality, mainly male, made it difficult for them to sell how this long and winding road into the technology fields would be worth it.

a. Mark’s Story

Mark began his computer science interest by fixing electronic devices, cellular phones, and mobile devices. Early on, Mark found that he enjoyed tinkering with mobile devices, which led him to start fixing and “jailbreaking” devices for other people in his neighborhood. Around 13, Mark’s parents brought him his first computer, which allowed him to expand his neighborhood business and begin to think about entering the STEM field after high school. Also, around this time, Mark began participating in MPS computer science courses, where he learned to code and app design.

Mark describes this early investment of resources and training as instrumental in moving from computers serving as a hobby or repair business to acting as a possible career. For example, his older sister also participated in MPS CS programming before graduation; although she did not pursue a computer science career, she did serve as an example and entrée for Mark into a CS Pathway. However, Mark greatly attributes his desire to continue in computer science to his teacher Mr. Dawson. Unlike the other students interviewed, Mark expressed no fear about
entering into a field that he will be vastly underrepresented. He talked about having the confidence to succeed by using the “hate (discouragement)” as fuel to continue stating,

“My parents and teacher built my confidence, you know. They told me I can do anything...especially technology. Do you know? They were helping me with this stuff...And critics and haters, help, you know? That built my confidence, too.

Researcher: “The haters? The haters built your confidence?”

Yup. (Interview 5/2021)”

Mark’s story describes a process of socialization that built his CS identity. He has a teacher that looks like him, from the technology sector he wants to go into. His supportive family pushes him through resources and social expectations into a CS pathway. What is fascinating about Mark’s story is how he has internalized this social pressure into a self-expectation of greatness. Mark’s understanding of his identity or the process used to shape his identity is not new or unique, its that it is difficult to attempt in a district with limited access to technology and teachers. He describes many students like him, fixing phones and tinkering in their bedrooms but unable to find their ways into a CS pathway, recalling,

Mark. So having a Black teacher means a lot. It means that you can do anything. You know? Having Mr. Dawson is a real blessing.

Researcher: Give me an example of what he has done to be such a great teacher?
Mark: Well, it makes me want to be a teacher, too, teaching other kids technology and stuff or how to use it. You know? Use codes and apps and stuff, you know? (Interview 5/2021)

Mark’s relationship with Mr. Dawson appears to be very strong and deep. Mr. Dawson’s work with students, particularly black males, has shaped Mark in such a distinctive way. Although he thinks the course could be a little more fun, his absorption of ECS and CSD principles is remarkable for building his healthy CS identity. When questioned about how the school can make CS programming better, he suggested the school provide students with greater incentive and employment, “No, like playing games to make money for laptops or computers.” The influence of others’ expectations of youth and their effects on educational outcomes may vary by the racial and ethnic group of the student and the type of “other.” Moreover, Simon & Starks (2002), view these expectations need to be unpacked and examined with youth in order for young people to receive and understand what is being expected and required. However, thinking deeper, mentorship is critical and essential to socializing young people into adulthood, and as Simon & Starks (2002) recommend, we must begin to take the idea of mentorship and its beneficial effects on students seriously.

Area 3: Celebrating, Encouraging Success, and Win

The areas to follow will focus on two participants, both young women of color who share Mrs. Torres as their CS teacher. Moreover, we contend that these two young women are examples of students who would not have entered or continued their CS education and pathway participation without their teacher support and mentorship through coursework and matriculation concerns. Several studies identified encouragement from non-family members to be almost as important as family support. They contributed significantly more to women’s decision to pursue
a CS-related degree than men (Wang, Hong, Ravitz, & Ivory, 2015). This component of direct teacher support is what we believe separates these two women from our earlier students.

Mrs. Torres (Mary and Abigail’s teacher), during her interview, spoke to how she regards her role as a Latina modeling CS ability and passion to students just encountering the STEM field for the first time

“I think of myself, and how I got involved, it was more of a manufacturing kind of way. Like I like to see how things run. And even with the -- like, the robotics, I think females are a little drawn to that. Like the action side...I think when they have seen things be built from scratch and learn how they can put their own touches onto it, that’s where the creativity comes from. And that’s what I think needs to be more pushed when we talk about girls. (Interview 5/2021)”

Mrs. Torres, similarly to how Mr. Dawson served as an example to Mark, sees herself as an example to young women of the possibilities they can achieve within the CS fields. That it is not just a boys club but a place that could be welcoming to everyone,

“There were a few young women interested and is looking at computer science. They sometimes say it’s a ‘boys club.’ One of the students (Mary) are interested in CS just because she is thinking about becoming a doctor or getting into more of a, like a bio-ed field, and just felt -- like she wasn’t sure how computer science fit into that. However, it was the reason I had to use to get her to join us.”

Mary’s story (Celebrating, Encouraging Success, and Win)

Mary, an African American student, started her involvement in CS programming in high school when she first encountered Mrs. Torres in the ninth grade. Additionally, Mary’s high school has a computer science course requirement, which forced her to take a CS class for the first time. She talked about fearing computer science classes and work during middle school
because she did not picture herself doing anything with computers, stating, “I felt like it was a good opportunity to learn something new, like nothing that I would have ever saw myself doing...I would have never thought it was what it is.” When asked when did she overcome her fear of computers, she replied, “Honestly, this year when I took computer science ... I wasn’t really a computer person, but I don’t know, this just opened up like a lot of different aspects for me to look at... It was fun, so I just liked it. So I don’t know.”

Mary goes on to talk about how Mrs. Torres helped her overcome her CS challenges like coding and programming. For her, coding was a challenge that she believed almost forced her to quit, but her teacher kept her motivated to continue and finish the project that she was working on. Mary regards Mrs. Torres as her biggest supporter,

Researcher: Who was your biggest supporter when you decided, “Hey, I’m going to take a class,” or you have to take a class, right?

Mary: “I think we had to, but...Mrs Torres she helped all of us understand and took her time with us, because it was new to all of us.”

Researcher: What were some things she did to help you be more comfortable and be more involved?

Mary: “When I had like questions and stuff, she took time out of her day, out of school hours, to open the Google Meet and help me go through some of the questions I was having and stuff. She didn’t have to do that, but she did (Interview 5/2021).”

We found it interesting that Mary saw her teacher, Mrs. Torres, as her biggest supporter, not her family or friends, which is how Mark and Peter regarded support in their lives. This
understanding could be an example of Wang, Hong, Ravitz, & Ivory (2015), suggesting that non-family members are more critical to women in pursuing computer science degrees.

Indeed, when speaking to Mrs. Torres, she reports focusing on celebrating accomplishments for her students. When we asked her about Mary’s struggle with coding and how Mary viewed her support, she described it as an intentional process that required her to be sensitive to the vulnerable position Mary had– her being new to CS training and one of the few young women in the class and club. So she believed she needed to celebrate successes as a way to reinforce the lesson and as a way to build a strong relationship that allows her to push students forward, stating, “It is like a math lesson, things build on each other, and I have to get students to stay interested until they can see the whole picture. (Mrs Torries, Interview 5/2021)”

Area 4: Awareness of Critical Educational Junctures

Like many urban districts with open enrollment, Milwaukee suffers from what one of our teachers describes as a “fluctuating in and out system of students.” Meaning that children who live in and outside the city of Milwaukee can attend any MPS school if seats are available. This fluidity in the student population profoundly affects the student-teacher relationship, particularly during middle school and high school transitions. Mr. Potter, a CS teacher in MPS, spoke about how he sometimes finds it difficult to build long-lasting, sustainable bonds with students because of the volatility of student attendance in his school.

Our teachers highlighted breaks within the traditional student matriculation (changing school buildings) as a location of vulnerability for students within a CS pathway. For example, Abigail and Mrs. Torries knew each other in middle school and had already formed a deep connection before Abigail experienced her 8th grade to 9th-grade matriculation break. All the teachers pointed to these breaks in matriculation as probably one of the most troubling aspects to
think about when attempting to create a k-12 CS pathway. They also pointed out Milwaukee’s unique open school system and the difficulties of tracking students from 8th to 9th grades.

Additionally, these teachers pointed out that student movement within the district, because of social and economic issues like home evictions, crime, and jobs, was a year-round problem that made it difficult to form healthy relationships over a student’s 4-year high school career. Nevertheless, on the student side, they were also concerned in their particular way about movement and matriculation break. Across student interviews, students spoke about the difficulties of transitioning from 8th to 9th grade and how this transition into “full-fledge pre-adulthood” included them beginning to access and decide their future career and life goals.

**Abigail’s Story**

Contrasting Mary with Abigail you find a similar theme of Mrs. Torrie’s encouraging her to continue in the CS field. However, unlike Mary, Abigail knew Mrs. Torries in middle school when she took her first CS discoveries (CSD) computer course. Abigail recalled struggling in her early experience in CS courses. However, she recalled how Mrs. Torries would take extra time to help her and encourage her to finish her CS discoveries module. Also interesting about Abigail is that she was going through a difficult time during her middle school years and often struggled in classes because of her fear of changing schools and the uncertainty of being a “girl in middle school.”

She regarded her time in the CSD course as a positive outlet that allowed her to experience success and happiness. She particularly highlighted how Mrs. Torries, her CSD middle school teacher, created a classroom that would “push her” into pursuing her interest.

“Well I learned a lot of the new stuff, and considering in seventh grade, it like wasn’t the best year, but when I had computer class, I learned stuff there, and I’m
learning more stuff now… I know more things than I did back in seventh grade. It was really calming when I would go to my computer class because it would always be fun, and we would be doing something, or we would continue on a project that we were doing.”

Additionally, she spoke about how Mrs. Torries would talk about her career and things she had done when she was young, particularly the idea that CS isn’t just a “boys thing.” Indeed, she went on to explain that Mrs. Torries would point out that CS could be fun and it could be a place for women interested in things like Math and Problem-solving.

Both Mary and Abigail demonstrate how a teacher’s care and intentional practices can motivate students, particularly female students of color, to enter a CS pathway. Mrs. Torrie sees her pedagogical approach as encouraging students of color, focusing on women in STEM fields. Additionally, Abigail’s story of early CS opportunities was key to her positive view of computer science as a possible career field. Her 9th-grade school has a CS course requirement; however, when she reencountered Mrs. Torrie in the ninth grade, she drew on her previous positive experience and personal connection to CS programming, which helped to ease her into a CS pathway. Which also allowed Mrs. Torrie to continue her push of students into the CS career field.
VI. Discussion

Ladson-Billings (1995) developed three criteria that undergird culturally relevant pedagogy (CRP): “an ability to develop students academically; a willingness to nurture and support cultural competence of students; and the development of a sociopolitical or critical consciousness” (p. 483). The teachers in her research believed “in a Freirean notion of teaching as mining” (p. 479), or drawing out already existing knowledge. This belief aligns with research on students’ funds of knowledge that has shown that children bring to school knowledge rooted in their home cultures (Moll, 2019). Although this research is not focused on student “funds of knowledge,” we believe this social science research orients you (the reader) into a mind of understanding how students’ belief systems influence how they interact with computer science pathways. For communities and school districts like MPS, leaders and practitioners must consider the social realities of students struggling to find economic opportunities and dodge what many perceive as precarious social realities.

Practitioners and scholars interested in developing computer science (CS) pathways must understand the nuance of lives and goals students encounter when navigating the tricky lessons of life. Indeed, since the reform movements of the 1980s and subsequent experimentation, Urban policies and school systems have been somewhat exposed to the whims and uncertainty of marketplace-driven student movement (Pendharkar, 2021). However challenging it has become to track and identify students who have taken CS courses in the past, the stories and research presented demonstrate that it takes teachers and time to shape young people into their future CS selves.

Early Opportunities and Mentorship
Estrada, Hernandez, & Schultz (2018) and their research on mentor–protégé dynamics show how their understanding of mentorship opportunities collated with how our participants entered the CS field. Estrada, Hernandez, & Schultz sees that mentorship happens best when there are (1) Instrumental support, provided resources and opportunity to the protégé to engage in goal attainment (Kram, 1985) (2) Psychosocial support, and (3) Relationship satisfaction (may include feelings of trust, empathy, respect, and connectedness). If we take a bird-eye view of how the students entered and continued into the CS pathway, we find mentorship at the center of our students’ (1) motivation and (2) identity formation. Each student encountered a mentor who focused their intrinsic and extrinsic values on building their career, job prospects, and social position within the larger society. For example, we can see through Abigail, Mark, and Peter’s experience how their interests (fixing electronics, playing computer games, and using coding and computer work as an escape from complex life issues) and motivation were shifted positively toward a CS future through their connection to mentors concerned with not only academic success, but social success.

Research has found that students most motivated to pursue STEM degrees became interested in STEM through childhood extracurricular experiences with nature and astronomy and that relatives or friends were the most substantial factors for igniting initial student interest in STEM (VanMeter-Adams al et., 2014). Across student interviews, this was the case; each student recalled how their early experiences interacting with elements of computer science coupled with a “mentor’s push” drove their desire to learn about CS principles. For example, Abigail’s early experience with CS learning in her 7th-grade year (the year she began Computer Science Discoveries) was marked by a negative schooling experience; however, her interest in coding and games gave her a reason to come to school and dream about becoming a computer
science through Mrs. Torries’s example. This early experience, coupled with the love and support she received from her teacher, marked a turning point for her. Her teacher was instrumental in her continuing in school and more instrumental in her returning to CS programming in high school. Although each student encountered mentorship in a unique form, each student agreed that their teachers and parents served as a triggering event that helped them begin to identify within the field of computer science.

**Why is Building Student CS Identity Important?**

During Mark’s (an African American Male) interview, he spoke about how his African American male teacher served as an example of what he could become. Mr. Dawson (Mark’s teacher) also talked about the mentorship aspect of his job and how he regards his unique position as “first being Black and second being a male in education,” allowing his students to see themselves in the field. He sees CS programming as an opportunity for young men, particularly black men, to find a career path of success. Moreover, Mr. Dawson can walk Mark through the pitfall and dangers he faces as a person from the field. What we see as the most critical work Mr. Dawson is doing is his unique understanding of the black male psyche or “the male psyche.” Mr. Dawson, during his interview, spoke about what he sees as a lone wolf personality within his young men. Although this could be classified as care, it is also a cultural nuance that Mr. Dawson, a black male, has a unique cultural window.

Fries-Britt & White-Lewis (2020), discussing black males’ experiences in STEM classrooms, found that when black males perceive positive faculty behaviors, they make deeper connections, which opens a space for increased learning and trust. Mark and Mr. Dawson are
acting out this relationship pattern. Mr. Dawson can cut through Mark’s “cool posturing” to his desire to succeed in the field of computer science. For Mr. Dawson, Mark’s story also takes on a much deeper and larger social phenomenon that troubles him when working with young black males. The need to separate themselves from the community. Studies have shown that as black men become more successful, there is an increase in depression and chronic medical conditions (Assari, 2016). This factor is something very few people outside the black male experiences are aware of; thus, mentors like Mr. Dawson see themselves as responsible for orienting younger black men into the social reality of being black and successful. In shaping Mark’s CS identity, it becomes essential that Mr. Dawson use an intersectional lens to prepare Mark for his chosen field.

We also believe Mrs. Torres (Mary and Abigail’s teachers) is also doing a similar job except approaching the students differently. Mrs. Torres also regards forming healthy relationships as a tool to encourage young women into a CS pathway. A significant issue in research about women is that they see themselves as lacking confidence in performing tasks (Liberatore & Wagner, 2020). For example, each of the boys demonstrated self-assurance when speaking about their CS abilities and knowledge, while each of the women used language that indicated unsureness. Mrs. Torries described her approach as building “young women’s confidence” and making sure they see themselves as equally deserving to be in the room. This thinking, like Mr. Dawson, demonstrates how having culturally responsive teachers could be a critical tool to encourage minoritized students into pathways. Moreover, these two examples

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1 A position of defense whether verbally or physically
illustrate the importance of diversifying mentors (teachers and industry professionals) when designing pathways into industries struggling to diversify.

**Critical Junctures as Locations of Vulnerability**

The final area focuses on what we see as locations of criticality. Our teachers highlighted breaks within the traditional student matriculation (changing school buildings) as a location of vulnerability for students within a CS pathway. For example, Abigail and Mrs. Torries knew each other in middle school and had already formed a deep connection before Abigail experienced her 8th-grade to 9th-grade matriculation break. All the teachers pointed to these breaks in matriculation as probably one of the most troubling aspects to think about when attempting to create a CS pathway. They also pointed out Milwaukee’s unique open school system and the difficulties of tracking students from 8th to 9th grades.

Additionally, these teachers pointed out that student movement within the district, because of social and economic issues like home evictions, crime, and jobs, was a year-round problem that made it difficult to form healthy relationships over a student’s 4-year high school career. Nevertheless, on the student side, they were also concerned in their particular way about movement and matriculation break. Across student interviews, students spoke about the difficulties of transitioning from 8th to 9th grade and how this transition into “full-fledge pre-adulthood” included them beginning to access and decide their future career and life goals.

**VII. Conclusion**

Building trust through practices that encourage critical reflection among students and educational professionals is key to understanding when and where systems leaders need to step in and help students. In this study, the students and teachers reflected on their experience and participation in Milwaukee Public Schools CS programming as initial access to a CS pathway.
Their stories and experiences describe a dynamic and fluid process that requires care to be paid to students’ extrinsic and intrinsic values.

Additionally, our examination suggests that authentic explorations of relationships, race, and difference served as an opportunity for individual and collective growth -- while fostering problem-solving and trust. Thus, these cases invite additional conversations about how trusting, focused and authentic relationships allow districts to build CS pathways free from assumptions about race and power. The influence of expectations of youth and their effects on educational outcomes may vary by the racial-ethnic group of the student and the type of “other”; it is, therefore, essential to unpack how youth experience and interpret these signals (Simon & Starks, 2002).

Understanding how students, particularly minoritized students enter into CS pathways for a district like Milwaukee is essential. Indeed, access is vital in moving students into CS pathways, but it is also necessary to understand why students become initially interested in computer science. Therefore, in future research, we will be looking at the characteristics of a healthy computer science pathway (displayed below). So far, we have identified four aspects for future research. Although this is not an exhaustive list and is still being examined with future research, we believe that if a CS pathway takes the time to encourage and emphasize these four elements, they will be on track to build a robust and effective path for students, particularly minoritized students and women into a CS career.
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