Engineer of 2020 Attributes and the Black Male Future Engineer: A Review of Literature

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Abstract

Historically, the United States of America has been an innovative and technically proficient forerunner. This position is threatened as the country's ability to develop competitive quantities of engineers, equipped to tackle the complex challenges of the future, has come under question. These challenges are wicked and unknown and will force engineers to use collaborate and use technical skills to solve social problems. With this in mind, the National Academies of Engineering launched the Engineer of 2020 project and charged its Committee on Engineering Education to develop a vision for engineering in 2020 and beyond. The Engineer of 2020 will be characterized by 10 attributes. The descriptions of these skills are vague; many institutions and organizations have characterized these attributes and created internal metrics by and through which they will develop these attributes in their students.

Yet, it is not the university's sole responsibility to develop engineering attributes in future engineers. Before beginning college, students have vast experiences both through formal and informal education, which may have already begun to foster these attributes. Additionally, there is a cultural transmission of knowledge and experiences which may inculcate students with interest towards interests in STEM fields. Thus, this literature review will discuss the engineer of 2020 attributes as discussed in historical and contemporary literature related to African Americans/Blacks, with a focus on males and precollege informal learning contexts. In this literature mapping review, the terms Blacks and African Americans will be used interchangeably. This work can impact the engineering education and diversity research by spurring increased conversation and research investigations of cultural practices and activities from informal settings which may contribute to engineering attribute development.

Introduction

This work will offer an additional perspective on how researchers can explore connections between the engineer of 2020 (E2020) attributes and the lived experiences of African American communities, particularly of African American male youth. As engineering educators develop engineers, who represent different cultures, it is important to understand their lived experiences and the social and historical occurrences that might serve as foundations for those experiences. These lived experiences can help us understand the intersection between a Black male student's lived experience and his journey on the engineering pathway.

Although Black males are earn only 4.8% of engineering degrees awarded[2], their presence in the discipline provides evidence of their ability to succeed in the field. Often our American society and their educational environments challenge Black boys by placing unseen obstacles in their pathways. One such obstacle is the significance American society places on practices, values and norms of the White majority community. The practices, norms and practices of African American students is not welcomed, included or understood. Thus, this literature review is a component of a larger study that seeks to identify valuable out-of-school experiences in the Black community that can be transferred to engineering contexts. We hope elucidate the connections between existing informal community practices of African American male youth (African Americans at-large) and the engineer of 2020 attributes. Our hope is that this work will

enhance the descriptions of the attributes to include experiences, values and norms of minority communities. This literature review will include both contemporary and historical literature. The contemporary literature included highlights the African American experience in today's context. While the historical literature can help the reader understand how today's context came to be.

Background

Informal precollege learning environments, whether explicitly labeled engineering or not, can serve a unique role for African American boys. These experiences may inspire them to pursue engineering degrees, can contribute to the students' development of engineering skills, knowledge, behaviors. Furthermore, the experiences may positively impact their engineering self-efficacy through their college years. Although all students may not continue into engineering careers these skills are transferable to many career and challenges. [1, 2] For those African American males, who complete STEM degrees, they will be our problems solvers who will address the technological challenges to come. While society is bombarded with propaganda around the challenges and failures that African American male students experience, engineering learning through out-of-school experiences prepare more African American boys and men to succeed and have a positive impact in our society both nationally and internationally.

During precollege years, Black boys participate in similar activities to other children; however, they face additional challenges. Much of the research on precollege informal learning experiences focuses on mathematics and science exploration. [3-5]Research also reveals that African American male children have to contend with their multiple competing identities, with respect to participating in science, technology, engineering, mathematics (STEM) related activities, and their status among peers in their community. There are examples of mathematically gifted African American boys who are learning to navigate their identities (i.e. Black, male, and mathematics) in the classroom.[6, 7] Students must come to terms with their diverse identities and the impact that has on their interest in pursuing STEM careers and education. Each student has diverse informal learning experiences. The students' diverse experiences have varied impact on the relationship between participation in the learning experience and academic gains.

Research Question

Future engineers should possess the engineer of 2020 attributes. But as of writing these attributes descriptions have not been situated and any specific cultural context in order to take into account the ways that culture can help foster them in people. The following research questions guide an investigation that explores relevant literature related to the intersectionality of race, gender and the engineering of 2020 attributes.
- *In what ways do the E2020 attributes manifest in the lived experiences of African American Male youth, as discussed in literature?*
- *Is there evidence in historical literature that the engineer of 2020 attributes are fostered in Black communities?*

Conceptual Framework

This literature review is part of larger research study designed using Cultural Community Wealth (CCW) [8] as a conceptual framework, Funds of Knowledge (FoK)[9], and the Engineer of 2020

report [1] as a conceptual framework. The study is largely situated in the Counter Narrative paradigm and uses CCW, FoK and E2020 in order to understand pathways to engineering for African American male youth. Community cultural wealth (CCW) emerged from the Critical Race theory tradition and through this framework researcher view their target populations as resource rich. CCW is an array of knowledge, skills, abilities, and contacts possessed and used by Communities of Color to survive and resist macro and micro forms of oppression. [8] Community cultural wealth is a counter-narrative approach to understanding communities of color and is evidenced by at least six forms of capital: aspirational, navigational, social, linguistic, familial, and resistant. Using a counter-narrative approach to investigating the lived experiences of Black male youth is significant given recent low capital and deficit representations of Black males. [10] Funds of knowledge is a similar more practice oriented framework which also guides this work. [9] This framework emerged from the perspective of precollege educators learning to name and value the experiences and knowledge that students have access to from their respective cultures. In this framework, the teacher is positioned as the learner of his or her students' cultural attributes. African American. For this literature review CCW and FoK will be used as more of a conceptual lens, through which the literature will be reviewed and understood. The primary framework for this review is Engineer of 2020 report.

In 2004, the National Academies of Engineering (NAE) released a report discussing the anticipated direction of the field of engineering in order to predict the enduring engineering attributes needed to support "success" and "relevance" in the profession. [10] As a collective the attributes are known as the "Attributes of Engineers in 2020." Table 1 details the attributes and the search terms used to find relevant literature. More detailed description of each attribute will be presented in the results section.

Table 1. Engineer of 2020 Attribute and synonyms used during literature search

Engineer of 2020 Attribute	Synonyms and Search Terms
Strong Analytical Skills	Analytical skills
Practical Ingenuity	Ingenuity, skill in planning, combining, and adapting to identify problems, finding solutions
Creativity	Creativity, invention, innovation, thinking outside the box, art
Communication	Communication skills, oral narrative skills
Business and Management	Decision making, prioritizing, managing people and projects, troubleshooting
Leadership	Service, leadership
High Ethical Standards	Ethical standards, religion (faith), values, belief system, morals
Professionalism	Professionalism, ethics, judgement, care, subject expertise
Dynamism, Agility, Resilience, and Flexibility	Dynamism, agility, resilience, flexibility, grit
Life-long Learning	Desire to be a lifelong learner, knowledge transfer, skills Transfer

Methods

The search criteria described below operated as keywords for searches in journal and library databases such as google scholar, Purdue University library database, and the SCOPUS database.

> **African American** (Black, Minority), **Males** (Boys, youth, adolescent), **Pre-college** (middle school, pre-college), **Engineering skills** (E2020, STEM skills), **Informal** (out-of-school settings, extra-curricular activities)

Figure 1. Search Criteria for Literature review

In bold are the core search terms and in parenthesis, are the equivalent search terms. For each engineer of 2020 attributes, definitions and scholarship[11, 12] informed the identification of proper synonyms. There was a separate search performed for each attribute. The references and the abstracts of the articles were reviewed for fit in the literature review and for preliminary themes across the literature. The articles were not reviewed for quality but the article must have been able to address most of the following questions:

- Do they explicitly discuss the skills in an engineering context?
- Does the work address African Americans?
- Does the work address African American males?
- Does the work address African American male youth?
- Is there a description of the attribute in the article?
- Is that description from the author or what it informed from the data?
- Is this pre-college focused literature or other? Describe focus in one word

Of the 95 articles returned from the search, 50 articles were reviewed for inclusion in this publication. The NVIVO qualitative coding software was the tool used to code each article for the ways that the author discussed or investigated any of the E2020 attributes using a priori (i.e. attributes) and emergent codes (which were later used as themes to organize the literature review).   See table 2 for the codes and respective descriptions.

Results - Literature Review

The engineer of 2020 attributes contribute to each subsection of the results section. At the beginning of each section, the attribute is introducing and a National Academies of Engineering (NAE) description excerpt will follow. [10] The NAE description is followed by a rich discussion of the related findings and emergent themes. Among the highlights of the results section are themes including: Racial identity; Role of family, community and educators; and the impact America's racialized history. There is rich discussion of how these themes emerged through the literature in the discussion section.

Table 2. a priori and emergent code descriptions

Code	Description
Engineer of 2020 attributes	Excerpts which provide evidence of the attributes (and respective synonyms) in the lived experiences of Blacks and specifically, African American youth.
Identity development	Emergent Code – Excerpts which related to racial , ethnic or gender identity
Mathematics and Science Knowledge	Emergent Code – Considered core attribute of engineers. This code relates to evidence of acquiring Mathematics and Science knowledge informal contexts.
Role of family, educators, community	Emergent Code – relates to any individual or program connected to family, educators (informal & formal), and members of the community.

Strong Analytical Skills

Basketball and card playing are two activities which demonstrate qualities of strong analytical skills. [13-15] These are two practices which are familiar to African American communities, at-large but may not have been experienced by everyone.

> NAE description – Strong Analytical Skills
>
> Even though the scientific knowledge that defines operating principles is expected to be more fluid and more complex, the core analysis activities of engineering design—establishing structure, planning, evaluating performance, and aligning outcomes to a desired objective—will continue.[1]

In Mahiri's [13] ethnographic investigation of the relationship between discourse features of African American male youth and basketball, Mahiri points to the role that basketball plays in providing young boys an opportunity to engage in analytical thinking activities. Additionally, the researcher observed linguistic connections between Black language styles and their abilities to communicate analytical thought processes such as classifying, sequencing, comparison, description, and persuasion. This observed relationship between a common non-academic athletic activity and a desirable engineering attribute has also been discussed in other work.

Nasir's [16] research delves into common non-academic cultural practices (i.e. basketball, dominoes, card playing) in the lived experiences of Black boys and their ability to translate skills between formal education and informal contexts. In her study investigating thirty-four middle school Black student athletes transition from middle to high school, Nasir [14] found that students exhibit ability for higher level mathematical thinking skills and ability to set evaluation goals as the structure basketball practice changes during their transition from middle to high-school. Nasir considers these mathematical thinking skills 'practice-linked statistical concepts.' Although the student-athletes exhibit mathematical understandings as they relate to basketball, many of these students are unable to translate their knowledge to formal education contexts. I agree with Nasir that "there are also social consequences to the way basketball is structured as players move from one level to the next. At each level of practice (from middle school, to high school, to college, to professional play), there is increasingly less room for less serious and less skilled players. As players move up through the funnel, there are more drastic consequences when they fall by the wayside."[14] In the context of pathways to engineering degrees and careers, this is problematic. Here we have students who are have skill in some mathematical content but are only able to express that knowledge in one context. When they are no longer able to play basketball (i.e. injury, cut from the team) many are unable to academically recoup. Perhaps helping students make solid connections between experiences and knowledge between contexts could help to retain them in the academic pathway which could lead to engineering.

Practical Ingenuity and Creativity

Practical Ingenuity and Creativity African American can be considered 'two sides of the same coin' in Black communities. Historically, in the Black community, oppression, poverty and structural racism have led to 'the struggle', which is a reality for many lower socioeconomic

(SES) Black communities and families. Along with other experiences which give way to creative thought and expression, the challenge of finding and creating solutions to problems in homes and communities, with few resources has forced the birth of more technical ingenuity and creativity within the African American community.

NAE definition – Practical Ingenuity
"The word engineering derives from *ingeniator* (Johnston et al., 2000). Yesterday, today, and forever, engineering will be synonymous with ingenuity— skill in planning, combining, and adapting. Using science and practical ingenuity, engineers identify problems and find solutions. This will continue to be a mainstay of engineering… By 2020 the need for practical solutions will be at or near critical stage, and engineers, and their ingenuity, will become ever more important." [1]

NAE definition – Creativity
"Creativity (invention, innovation, thinking outside the box, art) is an indispensable quality for engineering, and given the growing scope of the challenges ahead and the complexity and diversity of the technologies of the 21st century, creativity will grow in importance. The creativity requisite for engineering will change only in the sense that the problems to be solved may require synthesis of a broader range of interdisciplinary knowledge and a greater focus on systemic constructs and outcomes."[1]

In the introduction to this section, we discussed how the proverbial historical struggle common to many low socioeconomic Black communities contributed to technical ingenuity and creative problem solving. Ingenuity and creativity are highly desirable skills for engineers. Although unfortunate experiences might birth skills it is important not to understate the historical oppression that has placed communities in difficult circumstances. While these innovations are ingenious and creative many emerged from extreme necessity—from the "If not us, who will?" mentality. With this stated, the literature provided insight on creativity from the following perspectives: creativity tied to leadership, innovation, creativity as a counter-narrative, overcoming racial obstacles, creativity demonstrated throughout history, different types of creativity, and how creativity (in Black communities) differs from majority norms of creativity.

Excerpts coded as 'innovation' often represent examples of African American inventors and records of practical inventions in the Black community. These record provide evidence of "— skill in planning, combining, and adapting…using science and practical ingenuity [to] identify problems and find solutions."[1] Historically, African Americans were not awarded patents even though their inventions addressed some of the problems faced by society at-large. Yet, the existence of the inventions made by African Americans demonstrates their contribution to technology transfer, their impact on dispelling common narratives of inferiority and their ability to promote the idea of Black innovative excellence. [17] African American
Fouché has a comprehensive breadth of research on the topics of African Americans and their negotiation and engagement with technology. [18-22] Analysis of the relevant literature reveals a clear link between innovation, creativity, and the historical context of Blacks' engagement with technology. Fouché [22] discusses how the history of innovation throughout history goes back to

African contributions. In his review of the book, "The Inventive Spirit of African Americans: Patented Ingenuity" [23], Fouché re-asserts "throughout the history of Africa, great scientific and technological civilizations flourished, and African slaves brought to the American Colonies African forms of scientific and technological knowledge." [22] I agree with Fouché's review and critique of Sluby's work, when he states that it is important to acknowledge that the ability to create and exercise ingenuity alone doesn't distinguish the contributions of African Americans from any other group. He contends that the creativity and ingenuity of Blacks must be discussed within the context of issues of the Black leadership, Black identity and the American racial landscape. The context provides the necessary background information to understand the value of creativity and ingenuity in the Black community.

Communication

In this section of the review, the diverse characteristics and strengths of communication practices within the African American community will be discussed. Through the analysis themes emerged including: different types of communication, context of communication, limited transfer of skills to academic settings, communication skills valued within the community, and the role of family/community/educators.

NAE description - Communication
"…good engineering will require good **communication**. Engineering has always engaged multiple stakeholders—government, private industry, and the public. In the new century the parties that engineering ties together will increasingly involve interdisciplinary teams, globally diverse team members, public officials, and a global customer base. We envision a world where communication is enabled by an ability to listen effectively as well as to communicate through oral, visual, and written mechanisms. Modern advances in technology will necessitate the effective use of virtual communication tools. The increasing imperative for accountability will necessitate an ability to communicate convincingly and to shape the opinions and attitudes of other engineers and the public… The increasing imperative for accountability will necessitate an ability to communicate convincingly and to shape the opinions and attitudes of other engineers and the public."[1]

Some unique characteristics of Black communication styles include oral narrative skills acquired through storytelling, excellence in narrative comprehension about story character's internal state, non-verbal communication, diverse forms of argumentation, expressive speech, circumlocution, call response, and narrativizing. [15, 24-27] Children from Black communities may experience different aspects of these diverse communication styles but not have mastered all aspects of these styles. Additionally, some African American youth are able to make judgements on which narrative style is best for the given situation (i.e. codeswitching). [26]

Children's interactions with adults develop narrative skills, develop ways of thinking, remembering, reasoning and solving problem. Although researchers initially believed that Black youth use mostly topic-centered narrative, it is now understood that children can also employ multiple types of narratives. [28] Children also learn to employ multiple narratives with the practice of storytelling. African American adults and children participate in storytelling together through questioning, feedback and conversation. One of the key components of the

communication for the engineer of 2020 is communication that is "enabled by an ability to listen effectively as well as to communicate through oral, visual, and written mechanisms." While the communication skills of African American youth are diverse, there are two issues which might hinder more general success for children. These hindrances mandate that these skills (as with the other attributes) be further developed.

Children demonstrate narrative skills in their communities but this does not typically translate to academic success. There could my many explanations for this occurrence. But, the children's narrative skills which vary from the culturally accepted academic communication skills might give insight to this problem. Cultural mismatches exist between home communication practices and those which educators expect from their students. This is often where theories such the community cultural wealth [8] and funds of knowledge [9, 29] offer a framework that educators and practitioners can use to make stronger links between home and both formal and informal learning contexts. For example, researchers have found ways to link African American males communicating in cultural practices such as playing Spades, a card game, with the practice of argumentation in science classrooms. [15]

Business and Management

Business and management in the African American community is often tied to concepts of innovation, entrepreneurship and identity. As with many instances of entrepreneurship, need drives business in the Black community. Racism and segregation, had an unanticipated byproduct that no one could have planned - the birth of successful Black business which had a niche market, their own people. The following themes will be discussed and will help to situate the attribute in the lived experiences of Black people: service oriented entrepreneurship, respond to restrictive and racist policies, business strategy, racial identity, innovation, and attitudes towards entrepreneurship.

NAE description – Business and Management
 "In the past those engineers who mastered the principles of **business and management** were rewarded with leadership roles. This will be no different in the future. However, with the growing interdependence between technology and the economic and social foundations of modern society, there will be an increasing number of opportunities for engineers to exercise their potential as leaders, not only in business but also in the nonprofit and government sectors… New levels of sophistication will be needed as choices that affect physical, human, and political infrastructures and decisions that define priorities and objectives for a community, region, or nation are made."[1]

There is a rich history around African Americans and entrepreneurship. Post-slavery Black entrepreneurship often involved services and trade work that the White community viewed servile in nature. [30] By 1890, there were around 5000 Black operated business in areas such as hauling, moving, catering, barbering, and other personal services. [30] Within these business Blacks served both members of their own community along with White communities. However, the racial hostility increased during the Great Black Migration as Blacks moved from southern states into the northern United States in order to position themselves for success in the

manufacturing industries and increase the livelihood of their families. As racial hostility increased the business relationships between Blacks and Whites crumbled. At the same time, Blacks entrepreneurs were negatively impacted by the lack of public policies that protected Black business men and women in their attempts sustain their livelihood through capital and employment. The lack of public protection for Black entrepreneurs, increased racial tension during the Great Black migration and the increase of competition from recent immigrants drove Black entrepreneurs to innovate ways to sustain their business.

Entrepreneurs demonstrated resilience and innovation in their response to racialized practices that restricted their success. For example, Black entrepreneurs had to establish their own niche and increase business revenue, so they began face-to-face marketing in their own communities. This door-to-door sales strategy allowed for the entrepreneurs to avoid the racial barriers, decrease advertising costs, establish their niche market and get direct feedback from the customers through strong connections within the community. [30] Their work to overcome adversity seemed to strengthen the relationship between business management and the Black racial identity. There was also increased innovation in business strategy.

Although difficulties were faced by entrepreneurs in the early 1900's, similar difficulties are still evidenced by the discrimination that minority entrepreneurs face when seeking small business loans in today's market. [31] For example, two applicants apply for a business loan—one minority and the other majority—and may have identical credentials but minority applicant usually experiences more difficulty obtaining the loan and often will be charged higher interest rates. [7, 8]

Minority entrepreneurship is increasing and Black business ownership is largest in New York, Georgia, and Florida. [32] In 2007, Blacks owned business accounted for 7.1%, generating $137.5 billion.[32] Businesses typically offer similar services to those of the early 20th century; offering services in health care and social aid, repair, maintenance, personal, and laundry services. [32] Perhaps it is the success (although marginal at times) and mere existence of these businesses which promote positive attitudes toward entrepreneurship among African American youth. In a study of African American students' perceptions of entrepreneurship education, Ede, Panigrahi & Calcich [33] confirmed that students from families with entrepreneurs have more favorable attitudes toward entrepreneurship education than do students who do not have an entrepreneur in the family. However, this perception of entrepreneurship could also be a matter of education and exposure.

The rich history of Black business ownership and the strong evidence of Black business striving to succeed amid opposition and discriminatory practices are the types of lived experiences that African American children have access to from a community wealth perspective. In their description of the business and management attribute, the NAE describes "that the engineer with these skills will be able to work in diverse sectors and need new levels of sophistication to make choices and decisions that affect diverse infrastructures (i.e. physical, human and political)." I would argue that this rich history of Black business ownership and the obstacles that some succumbed to and others have overcome demonstrate evidence that some African American youth have access to entrepreneurial community wealth and that there could be implications for attribute development.

Leadership

Leadership is often a character trait that is identified and demonstrated in classroom and group settings. For the purposes of this review, both demonstrated leadership and environments which support the development of leadership characteristics will be discussed. From the literature, there is an interesting relationship between leadership and giftedness, which was explored in Bonners' research on giftedness of African American male youth in elementary school[11] and high school[34] . An additional theme considering translating leadership skills to future contexts has implications for 'Life-Long Learning." The impact of extracurricular organizations which provide mentoring also emerged as a theme. The Rites of Passage (RoP) programs will be a focal point for that discussion. [11, 35]

The NAE committee identified leaders in engineering as those who would "lead in shaping the ultimate use of technology and the government processes that control, regulate or encourage its use." With that perspective at the forefront, it is necessary to re-assert how historical leadership in the United States has been skewed to favor the racial majority. Actors in the racialized history of the United States have suppressed potential leadership which did not conform with majority norms, values and appearance. Although potential leaders may have been suppressed, the research included in this review provide evidence, that members of the African American community have opportunities to develop and craft leadership skills and have been serving as leaders within various contexts.

NAE description - Leadership
 "By 2020 we aspire to engineers who will assume leadership positions from which they can serve as positive influences in the making of public policy and in the administration of government and industry (p.50) …In preparation for this opportunity, engineers must understand the principles of **leadership** and be able to practice them in growing proportions as their careers advance. They must also be willing to acknowledge the significance and importance of public service and its place in society, stretching their traditional comfort zone and accepting the challenge of bridging public policy and technology well beyond the roles accepted in the past"[1]

Opportunities to learn and exercise leadership skills are often made available through organizations offering mentoring programs. [11, 35] Organizations such as the Boy Scouts of America, 100 Black Men of America, the Urban League, the National Society of Black Engineers, and many Black fraternities have established mentoring programs, which promote leadership development among Black male youth. [34] Woodland points out that benefits from positive and constructive mentoring relationship include decreases in first time drug users, school absenteeism, violent acts, and improvements in the behaviors of Black male youth in school and home. [35]

Rite of Passage (RoP) programs with mentoring components are particularly successful in the lives of Black male adolescents. The design of these programs have been informed by Egyptian-Kemetian practices, as interpreted by African American scholars and activists. [36] RoP is a culturally based intervention which serves to educate youth about their ethnic/cultural identity to strengthen their ability to have pride in their identity, improve self-efficacy and successfully

transition into adulthood. Not only do youth observe leaders in action but RoP programs also can provide opportunities for youth to develop leadership skills. Note, the cross-cutting theme of identity and its role in developing engineering attributes emerges in this discussion.

A final emergent and cross-cutting theme from the leadership literature is the role of family, community, and educators. Bonner [34] comments on the primacy of the family in the African American community. Discussion of leaders in the Black community are often of national political, activist, and community leaders. [34] Yet, family and members of the local community can also demonstrate what leadership looks like at a level that the youth can easily identify with and potentially emulate. Leadership as developed from this approach can prepare Black male youth with an understanding of the "significance and importance of public service and its place in society" and the need to "[stretch beyond] their traditional comfort zone" to work as a bridge between various stakeholders in new and evolving leadership roles. [12]

High Ethical Standards and Professionalism

The National Academies of Engineering consider Leadership complementary to high ethical standards and professionalism. This section of the literature review will shed light on the emergent themes of High Ethical Standards and Professionalism on the basis of their complementary nature. Themes which emerged from the analysis of the literature include: belonging to organizations, mentoring program affiliation, the value of faith and the role of family, community and educators.

> NAE description – High Ethical Standards and Professionalism
> "Complementary to the necessity for strong leadership ability is the need to also possess a working framework upon which **high ethical standards** and a strong sense of **professionalism** can be developed. These are supported by boldness and courage. Many of the challenges of the new century are complex and interdependent and have significant implications for the technologies intended to address them and the ways in which those technologies affect the planet and the people that live here. Effective and wise management of technological resources is integral to engineering work. The choices will be gray in nature, balancing (for example) economic, social, environmental, and military factors. Leaders, and those who influence these choices, will benefit from a sense of purpose and clarity. Successful engineers in 2020 will, as they always have, recognize the broader contexts that are intertwined in technology
> and its application in society."[1]

Simmons et al. [2] explored the relationship between African American college students in engineering disciplines, who developed the engineer of 2020 attributes through their affiliation with Black Greek (fraternal) organizations. During the interview, students shared their experiences with the fraternities and provided insight into the ways that they developed professionally. Within these organizations, students were expected to carry themselves as exemplary members at all time because they always represent the entire organization. As necessitated in the NAE definition, students demonstrated leadership through their sense of 'purpose and clarity' and they understood their role in the bigger picture. Furthermore, students shared that they developed interpersonal skills which are integral to maintaining a professional

image and developing a professional network. While this research highlights experiences of college students, it is fraternal organizations like these that provide mentoring experiences for young Black men. [14]

High ethical standards relate to one's morals and values. In the Black community, even as it relates to work and academics, faith and family are often the source of value and morality. In academic work, Jett [36] found that mathematics majors draw from spirituality and religious belief in order to overcome obstacles and achieve success. Some students felt that they were 'called' to or led by the Lord to complete the mathematics degrees and that along with encouragement from their families, that helped them to persevere.

In her comparative work on race, class and immigration, Lamont [37] addresses differences between working class Black and White men and their views on morality. Although she ultimately believes that Blacks and Whites in America live in "largely overlapping worlds (p.52). She does acknowledge differences in cultural values and morals. With respect to Blacks views of values and morality she says, "We saw that Whites and Blacks are not alike in the dimensions of morality and privilege. For Blacks more than Whites, protecting their families and guarding themselves against polluting elements and criminality through religion and tradition morality are key...(p.52)." A large component of morality as viewed by some on the Black community is solidarity, regardless of class. On this Lamont contends that this type of solidarity counters the notion that "as compared to class, race is losing its significance as a basis for differentiation and inequality (p.49).' This again speaks to the role of identity and community and their respective connections to developing engineer of 2020 attributes in African American youth. By analyzing literature relevant to High ethical standards and Professionalism situated in the lived experiences of African American people, one can see the opportunity for youth to gain exposure to these attributes.

Dynamism, agility, resilience, and flexibility

The technical and global environment of the future is unpredictable and potentially volatile. Engineers will must be prepared to address the future needs of those environments; they must demonstrate dynamism, agility, resilience, flexibility and grit. From the literature related to these terms situated in African American culture the following themes emerged: challenges experienced by African American males, resilience (overcoming obstacles), role of family/community/ educators, racial identity, discipline, and "the struggle."

> NAE description – Dynamism, Agility, Resilience, and Flexibility
> "Given the uncertain and changing character of the world in which 2020 engineers will work, engineers will need something that cannot be described in a single word. It involves **dynamism, agility, resilience,** and **flexibility**. Not only will technology change quickly, the social political-economic world in which engineers work will change continuously. In this context it will not be this or that particular knowledge that engineers will need but rather the ability to learn new things quickly and the ability to apply knowledge to new problems and new contexts."[1]

Black male youth experience some unique challenges. This is evidenced by recent calls for researchers, practitioners and community leaders to investigate the "trouble with Black boys"[38], to dismantle the school to prison pipeline [39] and to engage in research that promotes counter-narratives to the negative stereotypes which are exacerbated through media.

Even at the pre-college levels, African American youth face obstacles such as: family and peer pressure, academic integration, and identity conflicts. It is not atypical for urban African American pre-college males to acclimate struggling to survive ("the struggle) that Gratham [40] describes as "liv[ing] in homes and communities with limited adult supervision, excessive violence, and/support for homework." In this case, we see that the role of family/community/educators does not always have a positive influence on children. These youths must improvise to survive. Torrance [41], whose research on creativity and giftedness in Black males informed the developed of creativity scales, observed that the struggle experienced by these young men led to a high level of improvisation, flexibility and originality which in turn was used to survive inside and outside of school.

Intimately intertwined with what Torrance[41] called improvisation is the emergent theme, resilience. The theme of resilience provides evidence that although very difficult, some of these experiences provide Black male (and female) youth with the ability to adjust and overcome environments which are unpredictable and volatile. These knowledge and skills can be applied across contexts if the child is able to identify it and is provided opportunities and support to make the connection. Both Bonner [34] and Hawkins [42] refer to resilience as a protective mechanism. Bonner [34]references gifted Black students who have the ability to successfully assimilate to school context as having had to pay a "Black Tax." He continues to assert that some resilience in youth evolves in order to effectively neutralize and overcome by utilizing "protective practices" at critical time points of their lives. Both Bonner [34] and Hawkins [42] refer to protective practices such as self-esteem, family support, external support systems, and internal control.

Family and external support can operate as a protective mechanism for youth to depend on and use as they are trying to overcome and exercise resilience. Students who, even amidst obstacles, were raised in families with "high academic engagement, strictness, nurturance, and community connectedness" are also known to develop and exhibit resilience.[43] I agree with Bonners assertion, that ideally, the whole village should raise the child; however, all members of the community do not buy into this belief system. Therefore, Bonner concludes that it is most importantly the role of the parents to encourage resilience practices amidst wildly changing external and societal challenges. This literature began to explore the topic of why do some children succeed and others do not. As a response to calls for future engineers to show evidence of dynamism, agility, resilience and flexibility, these conversations about African American male youth improvising to succeed, exercising resilience and remaining connected to external support structure provide evidence of that their lived experiences can develop this attribute.

Mathematical and Science Knowledge

Mathematical and science knowledge is the heart of engineering. This literature review would be incomplete, if we did not present examples of African American practices which foster mathematics and science knowledge. In this section of the literature, we will discuss evidence that this knowledge can be explicitly developed in out-of-school settings as part of their lived experiences. Emergent themes include: the role of the family/community/educators, family time, out-of-school time activities related to academic achievement, basketball and dominoes. In the studies included in this review, researchers affirmed the role parents, both mothers and fathers.

NAE description - Mathematics and Science Knowledge
"Engineering must be grounded in the fundamental principles of science and mathematics. This foundation supports the development of new knowledge and the creation of safe, reliable, and innovative technologies that advance society and the human condition." [1]

In a study chronicling the lives of eight African American middle school aged boys [42], five themes emerged relating to contributing factors of success in mathematics: early educational experiences, recognition of abilities and how it was achieved, support systems, positive mathematical and academic identity, and alternative identities. Berry [44]reports that Bilal (one of the participants) attributes his love of mathematics to experiences he had with his father. Bilal's father played and challenged him with mathematics games and puzzles. This support is not unique to fathers, another participant responded that their mother also tested and challenged them mathematically. Other types of tools used by parents include magnetic letters and numbers, educational computer games, sing-along tapes, educational videos, reading aloud to children, and doing bills as a family. [44, 45] It was important for these children that their parents spent time helping to develop a mathematics identity and demonstrated interest in the development of that identity.

African American youth's mathematics and science identities can be developed during out-of-school time activities. [12, 46, 47] For example, in a study investigating urban fifth graders as they made connections between their science classroom and their lived experiences, a fifth grade girl commented that she visited a friend as she gardened and when her friend dug into the ground she saw different colors of soil and remembered a concept she learned from her science teacher. [48] Nasir [14] found that boys did demonstrate more sophisticated understanding of statistics as they matriculated from middle school to high school basketball teams. In addition to basketball, Nasir found that the game of dominoes, an activity familiar to many African American communities, allowed for players to devise and execute complex strategies as they had more experience with the game. [49] High school level players demonstrated an ability to mentally survey potential plays, calculate the possible final counts and then execute a play most successful play to earn them the most points. [16] When we examine experiences like these which at first might seem valueless to science, mathematics and engineering, research supports that they are quite valuable in developing problem solving skills, the ability to make decisions based off of empirical data such observations, drawn inferences, and prediction of future implications of those decisions. [15]

Lifelong learning

Lifelong learning is an attribute that did not appear explicitly in the literature review and for that reason we have left it for the discussion. We looked for literature that related to the desire to be a lifelong learner, knowledge transfer, and skills transfer. We also looked for literature that suggested evidence for learning continuously learning throughout academic and career lifecycles.

> NAE description- Life-Long Learners
> "Encompassed in this theme is the imperative for engineers to be lifelong learners. They will need this not only because technology will change quickly but also because the career trajectories of engineers will take on many more directions—directions that include different parts of the world and different types of challenges and that engage different types of people and objectives. Hence, to be individually/personally successful, the engineer of 2020 will learn continuously throughout his" [1]

Evidence from the previous attributes that suggests life-long learning occurs through discipline building activities such as rigorous basketball practice with high school teams. [50] As seen in Table 3, evidence of lifelong learning was also seen in leadership and professionalism attributes.

Discussion

The purpose of the literature review was to situate each of the engineer of 2020 attributes within the lived experiences of the African Americans, with a specific interest in African American male youth. We sought to answer the following questions:

- *In what ways do the E2020 attributes manifest in the lived experiences of African American Male youth, as discussed in literature?*
- *Is there evidence in historical literature that the engineer of 2020 attributes are fostered in Black communities?*

Using community cultural wealth as a lens, we believe that African American male youth have access to knowledge and experiences that can foster engineering attributes and that these experiences provide opportunity to have access to community wealth. By situating the E2020 attributes in the African American community and in historical and contemporary literature, we can begin to provide a different perspective of the value of these experiences and knowledge as well as to understand the unique ways that they contribute to the youths engineering identity development.

This literature review was more of a summary of the literature. For some attributes, it was necessary to provide historical context and for others the history was less important than the current evidence that this attribute can be fostered in their lived experiences. In this discussion section, we will take a more analytical approach and address the two themes that cut across many of the attributes. One question guiding this discussion and analytical review of the cross-cutting themes is how does what we now understand about the relationship between lived experiences of African Americans and the engineer of 2020 attributes contribute to the body of knowledge?

Cross-Cutting themes: (Racial) Identity; Role of family, the community, and educators

Two themes that seemed to serve as connectors across the literature are identity and the role of family, community, and educators. Moore [51] investigated the career trajectory of African American males in Engineering and found central themes related to "(1) strong interests in science, technology, engineering, and mathematics; (2) strong familial influence and encouragement; (3) strong aptitudes in science and mathematics; (4) meaningful academic experiences and relationships with school personnel; and (5) meaningful enrichment programs, opportunities, and academic experiences." The cross cutting themes from the literature review, appear to also mirror aspect of what Moore found. See table 3 for an early phase visualization of connections between attributes and themes.

Identity

Racial identity has an impact on how attributes are fostered in the Black community. This is a significant finding. This is not something that we expected to see as a common thread across the literature. Current researchers and policy makers address diversity and its role in solving engineering problems in different ways. We look at diversity engineering as social justice issue—in that historical oppressed people and all people have a right to sit the table. Some look at it from an economic prospective- more low SES- minority with degrees yield less burden on the government. While others declare that ethnic diversity allows for diversity of thought. Funds of knowledge scholars seek to identify aspects of students lived experiences within family and community and incorporate those experiences in the classroom. However, with respect to engineering education, we argue that we often fail to incorporate—or at least knowledge that a student's racial, gender, ethnic and cultural identity has shaped who they are since birth and that for African Americans their racial identity (at least as supported by this literature review) plays a major role in their learning.

Researchers are gaining insight on this; however, educators with ethnically diverse classrooms might experience difficulty incorporating racial identity into their curriculum. If African American children's informal learning experiences within are integrated with their racial identity, then how can we expect African American male youth to experience success along the engineering pathway when they are so often expected to ignore (set aside) their racial identity in the classroom? Furthermore, how can we anticipate success and spurn failure when their educators are unaware of the value that their racial identity has been throughout their lives and it is not integrated into the classroom? If we want to see increased representation in engineering of Black men, we need to begin to begin addressing the intersection of racial identity and engineering education approaches.

Role of Family, Community, and Educators

Family, community and educators impact how attributes are fostered in the Black community. This is not a surprising finding given a common proverb in the Black community that "it takes village to raise a child." Family, community and educators can have both positive and negative impacts on the development of engineering attributes in African American youth. Researchers have confirmed that positive impact that engineering parents can have on children. [52] We know

in the Black community, as with other communities, all parents do not have college degrees. However, positive parenting (regardless of degree) results in academic achievements. Parents who spend time reviewing homework, and helping students develop mathematics, science and engineering identities can often see an impact in their children's academic achievements. When students have positive adult role models-be it parents, mentors, or others- it positively influences the students in academic achievement and personal development. On the other hand, we also know that children from broken homes and those who live in unstable environments, typically do not have access to resources and have many difficulties to overcome and often this negatively impacts them.

The role of family, community, and educators is known information; however, because this theme emerged in seven of eleven attributes it appears that it is very important to the development of desirable engineering traits. This suggests, that at every point along the engineering pathway African American boys and men need an adult that models the positive role that "family/community/educators" have in their lives. Formal and informal pre-college educators, along with higher education administrators, faculty and staff must also take this into consideration. It seems that family, community and educators each play a role in the success of an African American child's life. Some children who have this positive impact throughout their childhood, experience success. Therefore, we suggest that school districts, community programs, and colleges must creatively include this within their structure if they hope to help African American students attain success.

Our understanding of the roles of these two cross cutting themes can build upon what we have learned about African American males along the engineering pathway. Racial identity and Family/community/educators represent both external and internal influencers on African American male's development. For some African American young men, as they are constructing their own racial identity (and come to understand who they are)—the world outside them plays an equal role in constructing what it means to be a Black young man. Additionally, African American males have a unique contribution to engineering knowledge because of racial and cultural identities.

Bonner[34] affirms a well-understood concept of the African American community—that the family is the unifying force. I also add the extended community to "family", primarily because in many African American communities there is a "It take a village to raise a child" mindset. This means that everyone in the community plays a role in the development of each child. This is very similar to Bronfenbrenner's ecological systems theory which addresses the ways that children engage with different systems in their environments. [53, 54] Family/community/educators represent a completely external force that shape the development of an African American boy but can also work to his detriment. Therefore, we (as researchers and educators) must understand our role in the lives of African American males and work to build upon the valuable knowledge they develop from their diverse lived experiences so that we can see strong indicators that the E2020 attributes have been nurtured and come to maturity in their lives. We work to mine their existing valuable attributes so they can be the engineers needed to solve the problems of the future.

Future Work

This literature review and discussion contribute to a research investigation of how out-of-school informal experiences foster engineer of 2020 attributes in African American boys and how those experiences and yield knowledge transfer. Previous studies investigating these attributes, explored their development in African American college students. It was important for our purposes that we attribute value to the precollege lived experiences of Black boys. Viewing the population as resource-rich, provides a lens through which, evidence of attribute development in their experiences can be unearthed. Future phases of this study will validate and build upon findings from the literature review, make stronger connections to cultural community wealth and funds of knowledge, and will include interviews from middle school African American children and college level African American men enrolled in engineering programs.

Table 3. Connections across a priori and emergent themes

	Strong Analytical Skills	Practical Ingenuity	Creativity	Communication	Business and Management	Leadership	High Ethical Standards	Professionalism	Dynamism, Agility Resilience, and Flexibility	Mathematical and Science Knowledge	Identity (Racial)	Family/ Community/ Educators	Life-long Learning
Strong Analytical Skills				✓						✓			
Practical Ingenuity			✓								✓		
Creativity					✓	✓			✓			✓	
Communication	✓		✓						✓			✓	
Business and Management		✓	✓						✓		✓	✓	
Leadership											✓	✓	✓
High Ethical Standards													
Professionalism											✓	✓	✓
Dynamism, Agility, Resilience, and Flexibility				✓	✓						✓	✓	
Math&Science Knowledge	✓											✓	

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