THE USE OF THEORY IN RESEARCH ON BROADENING PARTICIPATION IN PreK–12 STEM EDUCATION

INFORMATION AND GUIDANCE FOR PROSPECTIVE DRK–12 GRANTEES

NSF's mission of broadening opportunities for and expanding participation of groups, institutions, and geographic regions that are underrepresented in STEM disciplines is essential to the health and vitality of STEM endeavors and professions. NSF is committed to this principle of diversity and deems it central to the programs, projects, and activities it considers and supports. Discovery Research PreK–12 (DRK–12) and other programs in NSF's Education and Human Resources Directorate operationalize these goals by supporting projects that aim to increase the scientific workforce by engaging and building capacity in all people in STEM learning and professional training, particularly those from groups that have been traditionally underrepresented in STEM fields.

DRK–12 projects are expected to contribute to both theory and practice, and proposals are expected to be supported by a well-articulated theoretical framework. Some proposals and projects use a specific theory or theories as a framework for understanding and explaining influences on and mechanisms for broadening participation in STEM. Others use their research as a platform for testing or extending certain theories. Regardless of how they are used, theories provide a conceptual basis for designing ways to investigate, analyze, and understand complex problems, systems, and relationships. They influence every aspect of a research project, from study and instrument design to data collection and analysis to reporting.

This paper seeks to provide a resource for prospective DRK–12 grantees by identifying some of the theories that current and recent DRK–12 grantees are using in their research on broadening participation. It reflects the results of a synthesis process with a volunteer group of principal investigators (PIs). It offers information that might not be easily found or accessible, partly because some of these projects have not yet reached the publication stage.

This paper does not represent the universe of theories that DRK–12 researchers are using on broadening participation. Nor is it intended as a checklist of theories to be used or as a series of steps to be followed for using theories or for writing a successful NSF proposal. Rather, its goals are to help prospective scholars advance the study of broadening participation by illuminating some important aspects of the challenge that are worthy of theorizing, providing a diverse and illustrative range of examples of theories that are being used to understand broadening participation, and identifying some opportunities for extending the use of theory on this topic. We recognize that the examples included are numerous, wide-ranging, and not necessarily consistent or compatible with each other. Their inclusion here was based solely on their nomination by the volunteers who participated in this project.

In terms of our critiques—the topics we raise as potentially productive lines of research, the way we frame those topics, and the types of theories we identify under "Opportunities for the Future"—this paper pushes NSF research on broadening participation into new territory. While this group of current and former DRK–12 grantees believes that the paper has the potential to spur exciting new work on broadening participation, breaking new ground carries inherent risks, and we are not able to guarantee that proposals using these theories or following our critiques will be funded.

Some Challenges to Broadening Participation in STEM

Efforts to broaden participation in PreK–12 STEM education are important because certain groups historically have been, and continue to be, denied equal access to rich STEM learning opportunities. The groups of interest here include but are not limited to females, Blacks, Hispanics, Native Americans, English learners, and students with disabilities. For these groups, differential access to STEM learning can begin before kindergarten and takes place at all levels of the education system, ultimately resulting in fewer opportunities to pursue STEM majors and careers. The well-documented disparities in STEM majors and careers are detrimental both to these groups and to society because they limit opportunity and reduce diversity. Here we briefly describe some of the existing challenges to broadening participation as a way of identifying key leverage points for theorizing and studying broadening participation. The points raised here do not represent every obstacle to broadening participation nor do the descriptions fully elaborate each issue. Rather, our discussion of these challenges is intended as a starting point for a range of investigations into broadening participation.

Societal and contextual factors constrain the opportunities for students from underrepresented groups to develop identities as STEM learners and professionals, and to participate in activities that can stimulate those interests and identities. These challenges include, but are not limited to:

- the persistent image of STEM learners, majors, and professionals as White males, which often leads to practices in K-12 education that limit participation and are at odds with the goals of diversity and inclusion.
- differential exposure to STEM career options in students' homes, neighborhoods, and communities.
- differential access to supplemental learning or enrichment opportunities and extracurricular activities that could help stimulate students' interest and engage them in STEM.

School systems do not redress—and often reinforce—these inequities. In schools and school systems, some challenges to broadening participation include:

- the availability of teachers who are adequately prepared to both teach STEM content and engage students from all types of underrepresented groups in STEM learning that is meaningful to those students. Teachers (and administrators) who have implicit bias about students' interests and abilities to learn STEM, who do not use their power to enhance diversity, or who are not aware of instructional tools to encourage broad participation can unintentionally create classroom environments that limit opportunities for participation in STEM-related learning experiences. Professional learning that explicitly supports teachers in broadening participation is essential and would be beneficial for administrators.
- structural conditions such as the inequitable distribution of the kinds of facilities, personnel, and curricular resources required to offer both rich STEM learning experiences and differential access to STEM career and postsecondary education counseling.
- policies that separate English learners and students with disabilities from regular classrooms, and that track students into courses that do not prepare them for advanced mathematics or for some K–12 science and engineering courses.
- classroom structures that do not allow children with learning or language differences to demonstrate their knowledge and understanding in science and mathematics.
- the interaction of content and language, which is especially timely because of the language demands of new content standards. Students learn the language for STEM by doing STEM. However, a common view among K–12 educators and leaders is that students must learn the language of STEM before they can meaningfully participate in STEM activities; thus, many English learners are excluded from STEM learning activities.

- It is important to understand these factors and conditions as they relate to broadening participation and examine the role of educators, leaders, and policymakers in creating and perpetuating these inequities.

Progress in Research on Broadening Participation

Although participation in STEM still is not inclusive or as broad as it needs to be, research and theory related to broadening participation are advancing rapidly. NSF's inclusion of broadening participation as one of its "10 big ideas" has given the issue a sense of priority and urgency. Work from DRK–12 and other EHR programs has been at the forefront of broadening participation efforts, both in promoting the critical importance of the issue and in the research and theory-building work that supports broadening participation in STEM. These advances are evident in the range of theories included in this paper.

Advice about Using Theories

Broadening participation requires several types of change to disrupt patterns of inequity:

- **CHANGE** in societal beliefs (sociocultural, psycho–social, or attitudinal) and individual beliefs among educational leaders, practitioners, and policymakers about diversity and inclusiveness as they intersect with educational practices, learning, and the environments in which both take place
- **CHANGE** in the way educators, education leaders and policymakers, and educational systems recognize and respond to the need for inclusiveness, including how they view and engage with families and community actors
- **CHANGE** in what happens in schools and classrooms, including access to opportunities to learn, educational practices, the nature of STEM learning activities and behaviors, organizational structures and policies, and communities of practice for students and teachers

All of these desired changes should be connected with how the field theorizes these issues. Bringing new theories to bear on these challenges has the potential to change the conversations about broadening participation of traditionally underserved and underrepresented populations in STEM.

Broadening participation theory differs from subject area/discipline theory in that it specifically seeks to either explain why certain populations are underrepresented in STEM or to introduce policies and practices that will equalize access to STEM learning opportunities for underrepresented students relative to other populations. With these goals in mind, we offer the following advice for scholars who are seeking to use theories in their research on broadening participation.

As mentioned, this advice is not intended to be a step-by-step checklist; rather, it represents the considered reflections of funded DRK–12 scholars who are using theory in their research on broadening participation. We cannot guarantee that proposals that follow this guidance will be funded by NSF.

- **Explicitly position the research relative to at least one area of CHANGE described above, and select theories that inform how the proposed project will address that CHANGE**. In so doing, scholars should make their own assumptions explicit to avoid perpetuating a deficit mindset. It is important to recognize—and resist—the potential for unintentionally reinforcing the very beliefs, conditions, and structures that the work on broadening participation is trying to overcome. Theories should be contextualized to convey a larger understanding of the societal forces and the coordinated acts of individuals that limit participation and avoid blaming underserved students or their families. In a related vein, scholars also should consider theories that build on students' and families' strengths and assets and seek to emphasize positive characteristics that theories shine on their respective topics (e.g., the development of a science, technology, engineering, or mathematics identity; the building of agency and resilience; and a more responsive framework for engaging families).

- **Recognize the role that larger influences have long had on limiting participation in STEM for underserved and underrepresented groups**. In many ways, broadening participation begins in the classroom. At the same time, efforts to broaden participation take place in the complex system of education, so achieving the desired change involves understanding and addressing the relevance and impact of individual and institutional bias and other organizational factors that could impede or facilitate progress. Moreover, broadening participation also requires recognizing inequitable societal structures that have limited participation in STEM. It is important to analyze and understand how these structures intersect with the education system—and with the teaching and learning that happens within the education system—in ways that affect access and opportunities to pursue STEM that perpetuate educational inequities.

- **Address a theoretical void in practice and research**. Understanding what is currently not known and proposing ways to fill the shortage of research should lead to new understandings and approaches that move toward broader participation in STEM.

- **One theory is sufficient, but no more than three theories should be used in a single NSF proposal**. Where more than one theory is used, a theoretical framework is typically offered that summarizes how each theory contributes to the production of knowledge individually and synergistically. For example, theoretical triangulation is evident when the knowledge produced by a study informs three complementary theories.

- **Link theories to research design, and sustain those linkages throughout data collection, analysis, and reporting**. The theory or theories that guide research on broadening participation should influence every aspect of the study. Research questions, data collection, and analysis methods should be consistent with and clearly reflect the chosen theoretical perspective. The connection between theory, research design, and the implementation of that design should remain unbroken and evident through every phase of the project.

While having a theory in broadening participation work is essential, some funded DRK–12 projects have moved beyond the selection of an appropriate theory to the rigorous use of theory. This rigor is achieved when scholars can address, for example:

- **What is potentially PARADIGM-SHIFTING** about the research questions and the framing of the problem with theory? Answering this question requires that proposals consider how the field might have been wrong, uncertain, or superficial about how social or programmatic dynamics function with respect to STEM teaching and learning.

- **What is potentially TRANSFORMATIVE** about the knowledge that the questions and theory application might yield through research?

Answering both of these questions will strengthen the intellectual merits of the case and speak to the potentially broad impact of the work proposed—two key criteria on which all NSF proposals are evaluated.

The last section of this paper identifies theories that are potentially useful to the topic of broadening participation but are rarely used in this way. A tension exists when writing proposals between proposing innovative and cutting-edge ideas and providing something more familiar to reviewers. Bringing theories that others in the field are not yet using often raises questions for reviewers. The authors of this paper encourage bringing new theories and creative ideas to bear because it can benefit the field. However, it is important to connect new theories to what reviewers already know. Proposal developers who seek to break ground in this way should consider doing the following:

- Point out promising aspects of the new theoretical perspective as they relate to broadening participation

- Build a bridge between what is known or "recognized theory" and how the proposed framework provides a new way of looking at the problem

- Demonstrate how current theories have not led to practical improvements in STEM to support the need for theoretical innovations
- Clearly explain how the proposed theory informs a theory of change and how it could potentially bridge gaps in practice and benefit the fields
- Suggest reviewers who have a sound understanding of the theories in which the proposed study is grounded

Examples of Theories That DRK-12 Scholars Apply to Broadening Participation

NSF's Education and Human Resources Directorate commonly asks prospective grantees to consider how the theories and methods from a variety of disciplines might be applied to improving education in the STEM disciplines. To that end, this section illustrates several theories that DRK–12 scholars are currently using in their work on broadening participation, along with the projects that are using these theories and their associated research questions. As mentioned, the theories in this list are wide-ranging and are not necessarily compatible or consistent with each other, which is why we have chosen to present them alphabetically. They are intended to stimulate the thinking of prospective DRK–12 grantees by showcasing some of the many possible theories that are relevant to broadening participation.

AGENCY AND MATHEMATICAL AGENCY

Agency is a human quality defined by Albert Bandura as the capability to exert influence over one's functioning and the course of events by one's actions. Agency theory posits that "through cognitive self-regulation, humans can create visualized futures that act on the present; construct, evaluate, and modify alternative courses of action to secure valued outcomes; and override environmental influences" (Bandura, 2006, p. 164). Thus, human agency and individual motivation can manifest and prevail in opposition to larger, countervailing forces. Agency is not just individual; it is exercised within social practices. A related theory of mathematical agency involves students taking ownership of the mathematical ideas that they present (Powell, 2004, 2005). Mathematical agency manifests when students talk about the relationships among mathematical objects that they perceive as they are doing mathematics, as opposed to repeating what has been told or given to them. Students exercise mathematical agency when they define, redefine, and extend a problem, and when they try to make connections that the teacher did not explicitly request. Mathematical agency develops in learning environments where students feel safe in taking ownership of mathematical ideas and learning to discuss disagreements around mathematical ideas.

Relevant DRK-12 Projects

Collaborative Research: Computer-Supported Math Discourse Among Teachers and Students (NSF #1118888) PI: Arthur Powell

Example of Research Questions Being Explored

- How is mathematical agency shaped by joint solving of dynamic geometry problems in online collaborative environments?

CULTURALLY RELEVANT PEDAGOGY

Culturally relevant pedagogy is a theoretical model that helps students affirm their cultural identities and develop critical perspectives to challenge social inequities. Rooted in criticisms of reform efforts that can reproduce inequities by attempting to fit marginalized students into the existing social hierarchy, culturally relevant pedagogy can help students to view education as a vehicle for emancipation. For students to be successful, the knowledge they bring into the classroom must be acknowledged, explored, and used (Ladson-Billings, 1994, 1995). Gonzalez, Moll, and Amanti (2005) refer to this as "funds of knowledge." Their basic premise is that "people are competent, they have knowledge, and their life experiences have given them that knowledge" (pp. i–ii). Learning is understood as a social process that occurs within the context of students' lives; therefore, teachers should be willing to learn from students and their communities and align their instruction accordingly (Gonzalez, Moll, & Amanti, 2005). In observing teachers of African American students, Ladson-Billings (1995) theorizes that culturally relevant teachers believe that all students are capable of academic success, view their pedagogy as always evolving, see themselves as members of the community and see teaching as a way to give back to the community, maintain fluid student–teacher relationships, connect with all of their students, develop a community of learners, encourage students to learn collaboratively, understand that knowledge is not static and must be viewed critically, scaffold to facilitate learning, and know that assessment must be multifaceted.

Relevant DRK-12 (or Other NSF) Projects

TACIB: Transforming Academic and Cultural Identity through Biliteracy (NSF #1321339) PI: Mark Ellis; co-PIs: Armando Martinez-Cruz, Sam Behseta, Natalie Tran, Michael Matsuda, Kirk Vandersall, Janet Yamagushi

TEACH MATH (NSF #1228034) PI: Julia Aguirre; co-PIs: Tonya Bartell, Corey Drake, Mary Foote, Amy McDuffie, Erin Turner

Student-Adaptive Pedagogy for Elementary Teachers: Promoting Multiplicative and Fractional Reasoning to Improve Students' Preparedness for Middle School Mathematics (NSF #1503206) PI: Ron Tzur

Development and Empirical Recovery for a Learning Progression-based Assessment of the Function Concept (NSF #1621117) PI: Edith Graf; co-PIs: Robert Moses, Gregory Budzban, Peter van Rijn, Sarah Ohls

Examples of Research Questions Being Explored

- How do preservice teachers' knowledge, beliefs, dispositions, and practices related to integrating children's mathematical thinking and children's cultural, linguistic, and community-based funds of knowledge in mathematics instruction change as a result of a series of instructional modules for mathematics methods courses?
- How do local instructor, course, program, university, and community contexts mediate the implementation of these modules?
- What supports and challenges do preservice and early career teachers face in implementing instructional practices in their PreK–8 classrooms that integrate children's mathematical thinking and children's cultural, linguistic, and community-based funds of knowledge, and how do they negotiate these challenges?
- What are the relationships between early career teachers' knowledge, beliefs, dispositions, and instructional practices and their PreK–8 students' mathematics learning and dispositions?
- How can we enhance the ability of teachers to provide quality mathematics education?

SOCIAL CAPITAL

Social capital as defined by Coleman (1988) is a multi-faceted resource that exists in the relationships between individuals or organizations. It materializes when changes in those relationships facilitate action—typically action that enables individuals or organizations to accomplish goals that they would not be able to realize on their own. Social capital relies on trust, communication, and group norms. For students from groups that are underrepresented in STEM, social capital could increase their exposure to STEM-related careers and majors; enable relationships with mentors in those fields; help them navigate the educational system in ways that prepare them for STEM majors and careers; and create opportunities for internships, STEM-enrichment experiences, or other related opportunities. Social capital theory also can be used at the school or system level to understand how changes come about that broaden participation.

Relevant DRK-12 Projects

Collaborative Research: School Organization and Science Achievement (Project SOSA) (NSF #1119349, #1119359, #1338512) PI: Malcolm B. Butler; co-PI: John Settlage

Examples of Research Questions Being Explored

- To what extent does school organization (instructional practices, teacher background, relational trust, community ties, and school leadership) predict science achievement?
- What school-level background measures (e.g., percent of students qualifying for free and reduced-price lunch, percent of students identified as English learners, median household income) and what student-level variables (e.g., English learner status, special education status, and free and reduced-price lunch status) predict science achievement?
- How strong is the correspondence between teacher and principal perceptions of leadership (e.g., program coherence, inclusiveness, instructional leadership) within and between schools, and how well does correspondence predict science outcomes?
- What are the changes (or what is the growth) over time in science achievement, and how do aggregated student-level factors (e.g., social class, ethnicity, and language) and school-level variables (e.g., school leadership) relate to school-level changes? What is the relationship between school change in science achievement and outlier status?
- What aspects of school organization (e.g., social capital, trust, networks, multicultural dispositions) are associated with science achievements within a building? What are the varieties of school leadership (e.g., distributed, inclusive, data-driven) that exist within schools, and how do those relate to science performance? [from principal interviews]
- What organizational structures and leadership practices explain why some buildings are positive outliers? How do those structures and practices differ when compared with negative-outlier schools enrolling demographically equivalent students? What qualities are more closely aligned with reduced science-achievement gaps between students from different backgrounds and social classes? [from interviews and principal questionnaires]

SOCIAL CONTROL THEORY

Formal social control comprises the laws, government action, and institutional practices that arise in reaction to perceived deviance to maintain order and administrate punishment. It allows one to consider the behavior of the school, and how it sorts and allocates students into social outcomes, including careers and incarceration, through school discipline. The order, conformity, and obedience-seeking strategies (i.e., social control) to which race and/or gender groups are disproportionately exposed may be related to lowered levels of the qualities that are known to support success in STEM, including engagement and excitement, agency in learning and self-efficacy, collaborative problem solving and interpersonal confidence, and creativity and inventiveness.

Relevant DRK-12 (or Other NSF) Projects

Assessing Social Control in Charter and Traditional Schools via Merged Data to Broaden the Participation of Race-Gender Groups in STEM (NSF #1800199) PI: Odis Johnson Jr.

Race-Gender Trajectories in Engineering: The Role of Social Control across Neighborhood and School Contexts (NSF #1619843) PI: Odis Johnson Jr.

Examples of Research Questions Being Explored

» Do student STEM identities and postsecondary plans vary according to a school's reliance on social-control strategies and the type used after considering its level of social order?

» Are the behavioral regimes of charter schools related to lower or higher levels of creativity, ingenuity, and collaborative problem solving in comparison to non-charter schools?

» What is the cost in STEM performance on standardized tests for each disciplinary sanction a student receives?

» If disciplinary sanctions were equalized according to race/ethnicity, would we observe smaller racial test-score gaps in mathematics and science?

» Can we fill the STEM pipeline without first draining the school-to-prison pipeline?

SOCIOCULTURAL AND SOCIOLINGUISTIC THEORIES

Vygotsky's highly influential sociocultural theory posits that learning, understanding, and meaning-making happen through social interactions and are strongly influenced by culture. Vygotsky's work has spawned many related theories, including sociocultural and situated theories of language learning (e.g., Gee, 2005; Lave & Wenger, 1991; Rogoff, 2008; van Lier, 1995) that treat language as a socially constructed process, appropriated over time through meaningful participation with others. Sociocultural and sociolinguistic theories can provide insights into different dimensions of broadening participation, such as meaningful collaboration, dynamic interaction, and rigorous content learning.

ACTIVITY THEORY

Activity theory, and the related cultural historical activity theory (CHAT), are practice-based theories that examine the historical development of a system (e.g., a school system) within a cultural context, with a critical emphasis on power dynamics. Activity theory can be traced from the ideas of Marx and Engels and then to Vygotsky and his followers, who emphasize the importance of considering the interactions of cultural, historical, and psychological dimensions for understanding transformation and change (e.g., Engeström, 1992; Kuutti, 1996; Roth, Lee, & Hsu, 2009). Activity theory meticulously examines how change can be brought about, exploring topics such as how to improve the experiences of participants, improve equality, negotiate disagreements, resolve conflicts and tensions, investigate coercion, understand collaboration, study systems of power, and understand internalization of ideas and externalization of innovations. Activity theory examines both how these processes happen in the context of human interactions, and the role of tools and symbols in facilitating or restricting these processes.

Relevant DRK-12 (or Other NSF) Projects

Promoting Students' Spatial Thinking in Upper Elementary Grades using Geographic Information Systems (GIS) (NSF #1316660) PI: May Jadallah; co-PIs: Alycia Hund, Jonathan Thayn

Proposal for a Teacher's Guide to the Mathematics and Science Resources of the ELPFD Framework (NSF #1346491) PI: H. Gary Cook

Examples of Research Questions Being Explored

- How does collective and collaborative expertise emerge when using advanced technology in a STEM classroom?
- How does language impact teacher and student understanding of the nature of science, nature of engineering, and nature of technology?
- Does the new technology mediate how ideas and concepts develop and how students think about the role of technology in solving problems?
- What tools might mediate educators' shift to instructional methods that elicit, probe, and deepen students' disciplinary reasoning?
- How can we design tools to support the full inclusion of English learners in disciplinary discourse?
- What institutional factors affect educators' appropriation of these tools?

ACTOR NETWORK THEORY

Actor network theory (ANT), developed by Bruno Latour (Latour, 1999; Latour, 2005; Latour & Woolgar, 1979), has been used to describe how scientific knowledge is created, packaged, and disseminated. Recognizing that humans and nonhumans (e.g., the objects in a laboratory or curriculum materials in a classroom) shape and influence how meaning is made, ANT focuses on how actors come together in the work of making meaning. While not originally used to support the goals of broadening participation in STEM, ANT has been combined with other theories such as embodied knowing (e.g., Jones, 2013) to study how networks are constructed to either enhance or constrain efforts to broaden STEM participation (e.g., Buxton, Harper, Payne, & Allexsaht-Snider, 2017). Embodied knowing happens when students are kinesthetically engaged in the learning process. Bringing together embodied pedagogies and ANT can help us understand how to shape interactions to improve meaning-making—for example, how to get teachers to engage students in more open-ended inquiry. This theory is useful for exploring the relational ties within a given network.

Relevant DRK-12 Project

Language-rich Inquiry Science with English Language Learners through Biotechnology (NSF #1316398) PI: Cory Buxton; co-PIs: Martha Allexsaht-Snider, Allen Cohen, Laura Lu

Examples of Research Questions Being Explored

- How do material actants (e.g., curriculum materials) mediate social-group formation?
- How might a multinational, multicultural, and multilingual research team work together to reconceptualize professional learning for teacher educators with an eye toward broadening participation?
- How do teachers' actor-networks influence their practices with English learners in their classrooms?
- How can we engage students who become disengaged by middle school?
- How does engaging families, students, and teachers together support student learning?
- How does involving families in STEM learning support teachers in teaching STEM content?

COMMUNITIES OF PRACTICE

Communities of practice describes a process of social learning wherein people with mutual interest in a subject collaborate over time to share ideas and strategies, brainstorm solutions, and design innovations. Communities of practice are based on the idea of learning as social participation. Members of these communities are practitioners who engage in shared activities and build relationships that enable them to learn from each other; extended interaction and shared learning are essential components of communities of practice. Together, members develop a collection of resources, stories, tools, and effective strategies that allow them to improve their practice (Lave, 1991; Wenger, 1999). Communities of practice, both physical and virtual, allow teachers to come together in a supportive learning environment to reflect on their practice, share their experiences, and learn from one another (Kirschner & Lai, 2007), and could be created and structured to focus explicitly on broadening participation. STEM-related communities of practice might help underserved and underrepresented students create and explore their identities as STEM learners.

Relevant DRK-12 Project

Development and Empirical Recovery for a Learning Progression-Based Assessment of the Function Concept (NSF #1621117) PI: Edith Graf; co-PIs: Robert Moses, Gregory Budzban, Peter van Rijn, Sarah Ohls

Example of Research Questions Being Explored

- Can we empirically recover the levels of a learning progression for the concept of function?

SYSTEMATIC FUNCTIONAL LINGUISTICS

Developed by Michael Halliday (Halliday & Hasan, 2006; Halliday & Matthiessen, 2004), systemic functional linguistics (SFL) posits that language, in the process of being used, develops for meaning-making. Halliday and other SFL linguists (Gibbons, 2006; Schleppegrell, 2012) take the position that some disciplinary-frequent patterns of language usage (e.g., explicitness, precision, objectivity, or confidence) develop when they are needed to accomplish desired goals. Functional-language approaches support students in learning to make appropriate language choices aligned with goals related to content, audience, and mode of communication. A critique of SFL is that it privileges academic language over everyday discourse, which may limit participation of students who have less experience with academic language. To address this critique, some researchers have combined tenets of SFL with culturally sustaining pedagogies to propose a culturally sustaining SFL (e.g., Harman & Khote, 2017), which can better support teachers in valuing the language that students already possess. However, other critical sociolinguistic scholars (e.g., Flores & Rosa, 2015) warn that this approach may still be flawed when it comes to working with English learners and other minoritized students because no matter what these students learn to do with language, their language may never be seen as academically "appropriate" by many teachers and others from the dominant sociolinguistic group.

Relevant DRK-12 Projects

Language-rich Inquiry Science with English Language Learners through Biotechnology (NSF #1316398) PI: Cory Buxton; co-PIs: Martha Allexsaht-Snider, Allen Cohen, Laura Lu

Language-rich Inquiry Science with English Language Learners (NSF #1019236) PI: Cory Buxton; co-PIs: Martha Allexsaht-Snider, Allen Cohen

Examples of Research Questions Being Explored

- To what degree can science meaning-making be done effectively with everyday language? What are the limits of everyday language for meaning-making?
- How do the Common Core State Standards and the Next Generation Science Standards change the common genres that students should learn to engage in and how, specifically, should this affect the learning experiences that English learners receive?
- What are the potential benefits of bilingual-constructed-response science assessments for emergent bilingual learners, and how can perspectives from linguistically diverse classrooms help all students unlock the language of science?

UNIVERSAL DESIGN FOR INSTRUCTION AND ASSESSMENT

Universal design for learning is a theoretical framework based on scientific understanding of how people learn. It is designed to promote success for all students by allowing flexibility in how students engage with content and demonstrate their understanding. In a related vein, universal design for assessment seeks to increase participation of students with disabilities and English learners in general-education assessments through customized testing platforms. Applying principles of universal design for assessment promotes accurate measurement of students from diverse demographic backgrounds and abilities and reduces possible sources of construct-irrelevant variance that might lead to inaccurate measurement. Inaccurate measurements can yield test scores that do not reflect what students actually know, which in turn, can lead to flawed decisions about these students that limit their participation in STEM. Creating accurate assessments and accommodations for differently abled and linguistically diverse learners—who are underrepresented in STEM—permits teachers and universities to better understand the STEM capabilities of these groups.

Relevant DRK-12 (or Other NSF) Project

Measuring Early Mathematical Reasoning Skills: Developing Tests of Numeric Relational Reasoning and Spatial Reasoning (NSF #1721100) PI: Leanne Ketterlin Geller; co-PI: Lindsey Perry

Example of Research Questions Being Explored

- » What features of test items impact a student's ability to interpret and respond to the items, and how can we make them maximally accessible?

Opportunities for the Future

Here we briefly explore two different avenues for using theory in the study of broadening participation in PreK–12 STEM education. The first is to introduce some potentially useful theories or theoretical approaches that the DRK–12 scholars who participated in this synthesis have rarely seen applied to broadening participation in STEM—with a particular emphasis on new theories that are not mainstream and/or traditional theories that could be used in new and/or novel ways. The second is to identify some challenges, topics, or issues that are currently under-theorized and that could possibly benefit from more theoretical grounding. As with the theories presented in the previous section, these ideas are not intended to represent the universe of possibilities, nor do they signal an endorsement or a checklist from which investigators should choose.

THEORIES WITH POTENTIAL APPLICABILITY TO BROADENING PARTICIPATION IN STEM

- » **Constructivist learning theory**, or constructivism, refers to the idea that learners construct knowledge and meaning for themselves (Dewey, 1933; Piaget, 1972; von Glasersfeld, 1995). It recognizes that all children (including English learners and children with learning disabilities) have a knowledge that is not deficient or, arguably, even different; rather, that knowledge is a complex organism that brings with it the child's entire prior experience (McDermott, 1993; Moschkovich & Brenner, 2000).
- » **Critical race theory** is a theoretical framework that uses critical theory to examine race, racism, and anti-blackness, and to understand how race and power shape society and culture. In the context of education, critical race theory examines how race and white supremacy impacts curriculum, instruction, assessment, and funding, and proposes that race—a significant factor in determining inequity—can explain differences in educational achievement between White students and students of color (Dumas & Ross, 2016; Ladson-Billings, 1998; Ladson-Billings & Tate, 1995).
- » The **cultural ecological model** was originally developed in the context of exploring Black students' attitudes about and behaviors in school as adaptations to their ecological realities. These realities include a history of substandard educational opportunities, a White-dominated education system that ignores their cultural identities, and barriers to employment that prevent them from applying their education in meaningful ways (Fordham & Ogbu, 1986; Ogbu, 1987).
- » **Gender inclusion** focuses on the ways in which women and girls have been marginalized in science education, and how to engage them in meaningful ways by examining issues related to equity and access, curriculum and pedagogy, science culture, and identity development (Brotman & Moore, 2008).
- » **Gender structure theory** views gender as a social structure wherein opportunities and constraints are differentiated based on gender categories. Understanding gender as a social structure allows for analysis of the ways in which gender is embedded at the individual, interactional, and institutional levels of society and how gender inequity is produced at each level (Risman, 2004).
- » **Grassroots organizing** and leadership are used by Robert Moses' Algebra Project to improve mathematics literacy among students from low-income households and students of color. It mobilizes entire communities to create a culture of literacy around mathematics and science, which is believed to be essential for full citizenship in society and participation in a technology-driven economy (Moses & Cobb Jr., 2001; Moses, Kamii, Swap, & Howard, 1989).

- **Ideology in pieces** is a framework that works at the intersection of sociological and teacher-as-learner approaches to teacher education by analyzing the learning and transformation of individual teachers within the context of racially stratified structures of political and economic power in society (Philip, 2011).

- **Impostor syndrome** describes a person's perception of being a fraud, or impostor, despite academic or professional abilities and achievements that prove otherwise. Considerable research has been conducted on impostor syndrome in women, but it can occur among members of underrepresented groups because of cultural stereotypes and can be exacerbated by unwelcoming or exclusionary academic and professional climates (Clance & Imes, 1978; Kolligian & Sternberg, 1991; McGee & Bentley, 2017).

- **Intersectionality** is a framework used to examine how interconnected and overlapping systems of power impact the most marginalized in society. Within this framework, oppression does not exist on a single axis of identity but, rather, comprises combinations of intersecting oppressions based on social categories such as race, gender, or socioeconomic status. Understanding social exclusion and disadvantage requires examining the intersections of these multiple forms of oppression (Collins, 1990; Cooper, 2016; Crenshaw, 1989, 1991).

- **Labeling theory and self-fulfilling prophesy** describe the ways in which individual behavior may be influenced by the expectations and terms that others apply to them. Expectations about academic potential and ability, often influenced by students' social status or perceived natural differences between social groups, can result in differential treatment that contributes to students fulfilling low expectations, thus confirming original misconceptions about their potential and ability (Ferguson, 2000; Rist, 1970).

- **Microaggressions** are common verbal, behavioral, or environmental indignities that convey negative slights and insults toward people of color that can result in internal distress. These microaggressions can be perpetrated intentionally or unintentionally by members of dominant groups due to cultural conditioning that instills biases and prejudices about particular social groups (McGee & Pearman, 2014; Sue et al., 2007).

- **Social cognitive career theory** is a career-development framework for understanding how individuals exercise personal agency in the formation of career-related interests, and in academic and career choice and performance; how various personal, contextual, and experiential factors can impact self-efficacy, expected outcomes, and goal mechanisms; and how these factors impact different social groups in unique ways (Lent, Brown, & Hackett, 1994, 2002). This theory is built on Bandura's general social cognitive theory (Bandura, 1986).

- **Social justice leadership theory** focuses on eliminating exclusion and marginalization in schools by centering on issues of race, class, gender, and ability to design and implement inclusive schooling practices for students. This theory assumes that in order for marginalized students to receive a quality education, deliberate steps must be taken by administrators to implement school changes that promote equity and justice (Theoharis, 2007).

- **Social network theory** is a framework for studying social interactions that shift focus from formal organizational entities (school or district) to more informal connections between actors (teachers and administrators). Research suggests that these relationships are a primary determinant of the success or failure of school-change efforts and that enacting sustainable reforms requires attending to these social networks that create webs of understanding, influence, and knowledge (Daly, 2010).

- **Stereotype threat** describes a person's real or perceived risk of confirming negative stereotypes about their own social group. The fear of confirming negative stereotypes is thought to be a possible factor in academic underperformance and racial and gender gaps in educational attainment, and has been studied extensively among African American students (Good, Aaronson, & Harder 2008; Steele & Aronson, 1995).

- The **structural theory of racism** examines racial phenomena using a racialized social systems framework. Racialized social systems are economically, politically, socially, and ideologically structured by organizing individuals into racial categories that produce racialized group hierarchies (Bonilla-Silva, 1997). These hierarchies are replicated in educational contexts and privilege Whiteness while devaluing and stigmatizing students of color (Martin, 2009).

IMPORTANT DIMENSIONS OF BROADENING PARTICIPATION IN STEM THAT ARE UNDER-THEORIZED

In the process of preparing this document, DRK–12 scholars identified some important issues in broadening participation that would benefit from grounding in a theoretical approach:

- How to apply broadening participation approaches to similar ethnic/racial or gender groups within different contexts, climates and social locations
- The sustainability of successful approaches to broadening participation
- The role of parents, and how to support parent education and understanding of STEM
- How natural scientists, physical scientists, and engineers not trained in the social sciences can be engaged in learning about and thinking with social theories relevant to their work supporting broadening participation
- How broadening participation theories are perceived or thought of by White practitioners, faculty, and men.

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A Note on Process

This paper was prepared as part CADRE's ongoing efforts to support the DRK–12 community. The goal of this sub-project, which was launched in November 2017, was to synthesize the DRK–12 portfolio on broadening participation in a way that would be useful for the field. CADRE staff appointed a steering committee of current and recent DRK–12 grantees to lead the effort and invited all current DRK–12 PIs who had self-identified as working on broadening participation to participate in the synthesis activity. Together, the participating group decided that a paper on theory would be a useful contribution; this paper presents the results of our collaboration.

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SUGGESTED CITATION

Powell, A., Nielsen, N., Butler, M., Buxton, C., Johnson, O., Ketterlin-Geller, L., Stiles, J., McCulloch, C. (2018). The Use of Theory in Research on Broadening Participation in PreK–12 STEM Education: Information and guidance for prospective DRK–12 grantees. Waltham, MA: Education Development Center, Inc. Retrieved from http://cadrek12.org/resources/use-theory-research-broadening-participation-prek%E2%80%9312-stem-education-information-and.

This project is funded by the National Science Foundation, grant #1743807. Any opinions, findings, and conclusions or recommendations expressed in these materials are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.