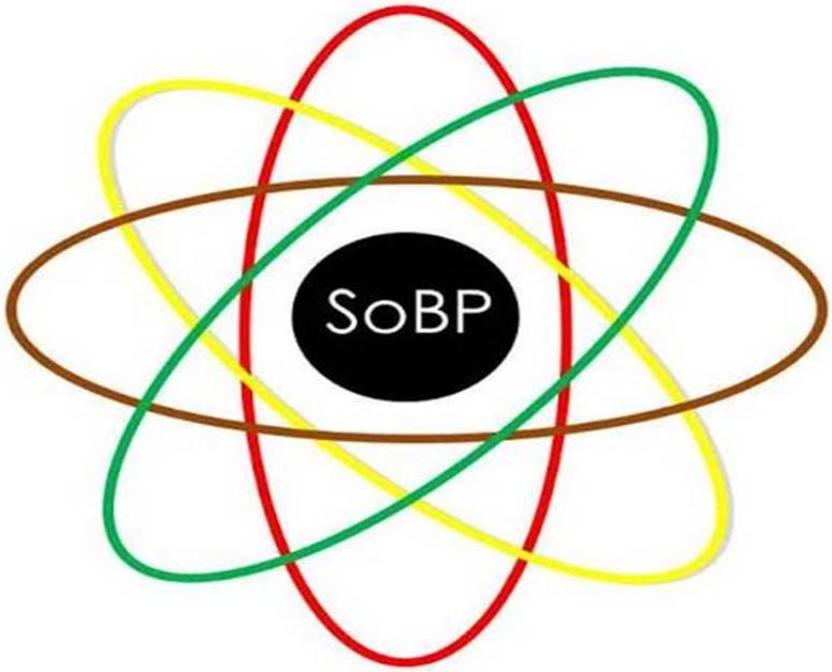
Report

Symposium
on the
Science of Broadening Participation

25-26 February 2016
Arlington, Virginia



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Supported by the
National Science Foundation
Science of Science and Innovation Policy Program

Table of Contents

Executive Summary

The need to develop and nurture a diverse and strong science, technology, engineering, and mathematics (STEM) workforce has occupied prominent positions on research and policy agendas in the United States and around the world. The presence of a qualified and agile STEM workforce for academia, government, and industry has long been recognized as central to economic progress, and the underrepresentation of particular groups in related fields increasingly has been problematized as wasted resources for building and maintaining a talented and innovative workforce. Referring especially to minorities, women, and persons with disabilities, related discussions have been linked directly to issues of productivity and growth, as well as to questions of social justice, inclusion, and fairness. However, how can academic institutions, government agencies, and various businesses appropriately design incentives, opportunities, and organizational structures to engage a diverse group of individuals in STEM for improved productivity and innovation?

Necessary to address this question and to create positive change is a **Science of Broadening Participation** (SoBP), an assembled and systematic body of knowledge ready for use for broadening participation in STEM education and the STEM workforce. While a large and rich literature exists relevant to this issue, related policy and programmatic efforts have faced a variety of challenges in research and application. Recognizing the complexity and urgency attending this matter, the National Science Foundation's (NSF) Committee on Equal Opportunities in Science and Engineering has recommended that "NSF should implement a bold new initiative focused on broadening participation of underrepresented groups in STEM." The Symposium on the Science of Broadening Participation was convened to engage the newly emerging SoBP in response to and in the spirit of that recommendation for "a bold new initiative."

Organized by Kaye Husbands Fealing (George Institute of Technology) and Connie L. McNeely (George Mason University) and supported by NSF's Science of Science and Innovation Policy (SciSIP) program,[1] the symposium was held 25-26 February 2016 in Arlington, Virginia, convening scholars, researchers, practitioners, representatives from funding organizations, and policy analysts, with the aim of determining the scope and analytical features of the SoBP and related practice.[2] In consideration of various stakeholder interests and positions, an important symposium goal was to explore strategies for capacity building and broadening STEM participation and to develop relevant research and action agendas. Accordingly, key tasks for participants included delineating and engaging SoBP as a critical issue for authentically transformative dialogue and action. To that end, the symposium included a variety of summative presentations and in-depth roundtable discussions to engage seven thematic questions identified as critical areas for SoBP delineation and engagement.

[1] Award #1551904 and Award #1551880

[2] For additional information, see the symposium website: http://sobp-conference.weebly.com

Thematic Question Engagement

1. **Why is there a need for a *scientific* approach to broadening participation in STEM fields?**

Although some increases have been observed in the STEM participation of underrepresented groups, significant disparities in related educational attainment and employment patterns remain. To effect positive change, a comprehensive and systematic scientific approach is needed for improving awareness and understanding of the processes that lead to the inequitable distribution of educational, social, and professional opportunities, and to the subverted productive contributions that could otherwise be made to society. There currently is a relative lack of assembled knowledge ready for use for broadening participation in STEM, and related symposium presentations and deliberations pointed to the urgent need for an SoBP offering coherent, consistent, comprehensive, and curated knowledge and data for research and decision making on broadening participation in STEM educational attainment and related workforce development and mobility.

2. **What are the frameworks that *should* inform assessment of underrepresentation relative to employment, education, and policy processes and outcomes?**

Science, as a system of knowledge, thrives on established frameworks, processes, and heuristics for addressing complex problems. As such, the delineation of theoretical and research frameworks is critical to conceptualizing a SoBP. Accordingly, symposium participants considered both new and existing frameworks to support a scientific approach to understanding and informing assessments of participation and inclusion relative to STEM employment, education, and policy processes and outcomes. Primary attention was given to engaging institutional and transdisciplinary logics as complementary and integrated frameworks for understanding problems, issues, and gaps in knowledge and as tools for investigating them in rigorous and replicable ways.

3. **What are the evaluative measures that should be used to identify underrepresentation in STEM fields?**

Evaluation and metrics are central to conducting scientific research and to determining the applicability and value of a given approach. Accordingly, identifying and developing valid and relevant metrics and tools for research and assessment are fundamental tasks for establishing a SoBP. Symposium participants probed existing data that might be leveraged to capture and understand underrepresentation and related processes in STEM fields, as well as addressing the limitations of those data. In addition, participants discussed needs for quantitative and qualitative data for rigorous SoBP assessment. Principal consideration was given to evaluative measures for identifying and studying participation and inclusion, along with the need for new data and new metrics, and their broader impact and analytical breadth, for developing more in-depth contextual understanding and fuller explanations across related issues and fields.

4. **To what extent is education both means and ends in STEM participation?**

The SoBP encompasses education as both means and ends for success in STEM educational attainment, disciplinary community building and networks, and related workforce access and mobility. Taking education seriously as a social institution, symposium participants considered issues regarding contextualizing educational access, opportunities, and outcomes and their broader implications for STEM participation and success. Discussions covered a variety of issues related to broadening participation in the education pipeline, including pedagogy, access and barriers in pursuing STEM education, trends in representation, and improving educational outcomes for students from underrepresented groups. Critical issues were identified for directed SoBP study, such as the need for a more strategic dialogue, along with new, more dynamic and inclusive educational paradigms to encourage a more diverse STEM community.

5. **How has the U.S. workforce been affected by underrepresentation of minorities, women, and people with disabilities?**

Discussing SoBP relevance to studying issues such as occupational access, opportunities, and outcomes, comprehensive and integrated investigations were called for on matters related to recruitment and retention issues in STEM-related occupational fields and on motivation and mobility in different sectors, professional networks, and organizational and institutional change. Lack of diversity and participation in STEM across academia, government, and industry employment sectors was framed as an expression of processes reflecting broad societal dynamics and relations, that is, as resulting from hierarchical relations and social and institutional barriers to occupational opportunity and access. With that understanding, a critical need was identified for more research on the value and relationship of workforce diversity for obtaining competitive advantages and progress. The examination of such issues was emphasized as critical for understanding STEM workforce dimensions and participation dynamics. In particular, policy making and implementation processes were questioned relative to STEM workforce disparities and representational outcomes.

6. **What are the social implications of broadening participation in STEM?**

A principal aim of the symposium was to explore strategies for capacity building and broadening STEM participation, especially as regards underrepresented minorities, women, and persons with disabilities. Discussion largely turned on the recognition that the relevant processes, structures, and relationships are deeply institutionalized and culturally enduring, and that finding ways to disrupt such patterns is a critical task for STEM development and expansion. To that end, various policies and programs were examined as concrete examples that offer lessons for broadening the participation and inclusion in STEM of minorities, women, and persons with disabilities, and their broader implications for social wellbeing more generally. Particularly emphasized were value added dimensions of broadening participation and the need to anticipate and design contextually sensitive intervention policies and programs for effective participation and inclusion.

7. **What are clear evidence-based pathways to broadening participation in STEM fields within and across academia, industry, and government?**

The SoBP focuses on developing and leveraging STEM educational and workforce diversity for broader inclusion and transformation, addressing strategic approaches for adapting, enhancing, advocating, and increasing participation and productive contributions. To that end, the SoBP will be theoretically driven and methodologically rigorous, and will offer pragmatic and grounded pathways to determine evidence for informing efforts to broaden participation. SoBP research will be conducted to determine what works and what is needed to broaden participation and effect diversity, with the goal of informing the development of relevant policies, programs, initiatives, and interventions. Along those lines, symposium participants were tasked with process delineation and identification of intervention research and applications, aimed at developing innovative pathways toward new theories, practices, and metrics for broadening participation and representation in STEM.

Roundtable Discussion Points

The symposium roundtables brought together groups of experts to address SoBP in relation to frameworks, measures, education, and workforce issues. The roundtables were organized to encourage discussion of the SoBP, working toward establishing sustainable, action-oriented research and policy agendas for bringing equitable representation and inclusion to all aspects of the STEM enterprise. Several key points were derived from the roundtable discussions:

- Successful frameworks for understanding and assessing STEM participation should be inclusive of stakeholder input, consider the goals and motivations of different groups, including underrepresented students and workers, and be powered by data measuring related behaviors and outcomes.
- More high quality longitudinal studies and data on participation and inclusion are needed in direct engagement and development of a SoBP.
- New and better contextualized models of STEM participation and inclusion are needed, and should be central to SoBP practice.
- A need exists for both top-down and bottom-up approaches in research and policy development, with applications stressing the coupling of top-down and bottom-up interventions for effecting cultural change within institutions to support diversity and inclusion goals.
- Applied, community-oriented research might be more aligned with goals and motivations of students from the targeted groups, and might better inform policies and programs for encouraging broader recruitment and retention in STEM education and later in the related workforce.
- SoBP and STEM researchers, educators, and practitioners should engage with and draw from local and other relevant communities as role models and mentors, through both formal and informal outreach and partnership initiatives.
- The SoBP community should leverage systems approaches and research methods to examine the extent to which a SoBP system exists, and how the systems framework can support researchers in identifying and assessing disparities in STEM participation.

- The development and dissemination of data collection, sharing, and use standards would facilitate inter-institution, inter-field, and international research in support of SoBP goals.
- Possibilities for blanket restricted data use agreements across data collection entities should be explored and pursued, as appropriate, to facilitate relevant research.
- Educational paradigms and pedagogical approaches need to be refreshed in light of new and evidence-based methods (e.g., growth mindset approaches to problem solving).
- There is a need to "demystify the ivory tower" and to make expectations and evaluation criteria transparent to students to support recruitment and retention in the STEM pipeline.
- An inventory of successful interventions should be conducted (and updated and maintained) to support SoBP and work to bring successful programs to scale.
- Promotion of more academia-industry-government partnerships should be pursued to keep STEM curricula and workforce needs in close alignment.
- Distinctions between diversity and inclusion must be understood in research and policy development, with diversity viewed more as a "check the box" idea based on simple numbers of persons and inclusion viewed more broadly in terms of quality of interaction and intentional recruitment and retention of underrepresented persons.
- Increased and improved training is needed to recognize and address bias, particularly implicit bias, at all points and at all levels of the STEM pipeline.
- Sustainability and the "normalization" of diversity must remain central to SoBP research and policy agendas.
- Evidence shows that diversity leads to better science and is correlated with increased productivity and positive performance. The onus should be put on skeptics; let the burden of proof be on those who argue that diversity impedes excellence in STEM.

Conclusion

The Symposium on the Science of Broadening Participation brought together scholars, researchers, practitioners, representatives from funding organizations, and policy analysts to determining the scope and analytical features of the SoBP and related practice. A principal aim of the SoBP is to explore strategies for capacity building and broadening STEM participation. Accordingly, key tasks for symposium participants included delineating and engaging SoBP as a critical issue for transformative dialogue and action. In the end, there were four key takeaways — indeed challenges to the SoBP community of practice — regarding work that is needed to provide a contextualized and sound evidentiary basis for broadening the STEM participation and representation of women, minorities, and people with disabilities:

- Curated knowledge from various areas of study related to understanding and assessing underrepresentation in STEM fields.
- Curated data, metrics, and statistics from various areas of study related to understanding and assessing underrepresentation in STEM fields.

- Curated knowledge from various areas of study assessing educational attainment and effects, contextualizing educational access, opportunities, and outcomes, and identifying critical causes of underrepresentation in STEM fields.
- Curated knowledge from various areas of study for identifying workforce dimensions and dynamics, contextualizing occupational access, opportunities, and outcomes, and investigating recruitment, retention, and network characteristics that result in underrepresentation in the STEM workforce.

In addition, participants stated that any SoBP program should emphasize and foster scalable and sustainable solutions based on evidence. The need to communicate the value of a SoBP also was emphasized by participants, positing particularly the importance for the research to have practical resonance. Moreover, participants urged researchers to embrace the challenge of the SoBP and to take the risk of developing disruptive paradigms that could support real and positive changes leading to the broadened participation and inclusion of women, minorities, and people with disabilities in STEM.

Acknowledgments

Networks are catalysts for action. The Symposium on the Science of Broadening Participation (SoBP) brought together academic scholars and practitioners from several fields to synthesize knowledge to inform pathways for increasing the representation and inclusion of women, minorities, and people with disabilities in science, technology, engineering, and mathematics (STEM) disciplines and the related workforce. The organizers of the symposium — Kaye Husbands Fealing (Georgia Institute of Technology) and Connie L. McNeely (George Mason University) — are grateful for the contributions of participants who helped to organize, inform, and sponsor knowledge sharing during the formal and informal interactions among attendees.

First, we are grateful to all of the scholars, analysts, and practitioners who attended the symposium. We especially thank our plenary speakers and panelists who brought a wealth of knowledge and skillset to the table, enhancing the learning environment and highlighting pathways for positive change. Those speakers were Jeryl Mumpower, Heather Metcalf, Hannah Valantine, Amanda Bayer, Donna Ginther, Paul Baker, Mary Ann Leung, Tamitha C. Tidwell, Emorcia Hill, Gertrude Fraser, Roli Varma, Jong-on Hahm, Ingrid Padilla, Cecilia Conrad, Bill Valdez, and Krishna Athreya. The knowledge unpacked, shared, and assembled into actionable approaches and means for the greater inclusion of women, underrepresented minorities, and people with disabilities in STEM fields will inform policy and practice going forward. During the symposium, participants were eager to take new ideas and tools back to their organizations and put them to work for the improvement of learning environments and the workforce. We give special thanks to the many National Science Foundation (NSF) program directors from several directorates who spent time with us, absorbing new ideas from other participants and sharing information on new initiatives in their programs and at NSF in general, particularly the Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES) program. We also appreciate Assistant Director Fay Cook's remarks that were informed by her discussions with leadership at science agencies and in the United States Congress on the importance of broadening participation in STEM.

Second, our roundtable moderators deserve our heartfelt thanks for listening intently to what their colleagues were saying at their respective tables on frameworks, measures, education, and workforce, encouraging everyone to have a say in the guiding principles for the SoBP and synthesizing diverse knowledge sets, expertly offering solid outcomes and recommendations for advancing this emerging area. The roundtable moderators were:

•Frameworks
Jong-on Hahm, George Washington University
Erik Kuiler, George Mason University
Daniel Styer, Sacramento City College
Patricia White, National Science Foundation

•Measures
Robbin Chapman, Wellesley College
Lisa Frehill, Energetics Technology Center
Samuel Myers, Jr., University of Minnesota
Yu Tao, Stevens Institute of Technology

•Education
Ana Ferreras, National Academy of Sciences
Marilyn Mobley, Case Western Reserve University
Kimberly Saunders, University of Delaware
Cheryl Wilga, University of Alaska, Anchorage

•Workforce
Mary Ann Leung, Sustainable Horizons Institute
Ernest McDuffie, The Global McDuffie Group
Willie Pearson, Jr., Georgia Institute of Technology
Ester Sztein, National Academy of Sciences

Erik Kuiler, Samuel Myers, Jr., Ana Ferreras, and Willie Pearson, Jr., gave presentations at the end of the first day, summarizing roundtable discussions and offering direction to participants on how SoBP should be framed for use and for further research.

Third, the writing of this report was greatly aided by careful notetaking during the roundtable sessions. The Roundtable Note Takers were Brian Donahue, George Mason University; Kevin Donahue, University of Mary Washington; Patricia Donahue, George Mason University; H. Aaron Finney, George Mason University; Joel Hicks, George Mason University; Lutheria Peters, George Mason University; Alfred Sarkissian, George Mason University; Thomas J. Scavone, George Mason University; and Katie Seely-Gant, Energetics Technology Center. We also thank Katie Seely-Gant for her invaluable assistance in reviewing symposium transcripts and notes for our use in the preparation of this report.

Fourth, we thank the research assistants, Gia Cromer (George Mason University) and Sana Surani (Georgia Institute of Technology) for their tireless efforts with logistic arrangements for conference participants, interacting with venue staff to ensure that we could focus on learning from one another, and for developing the website, which continues to host contact information for participants and (importantly) a comprehensive list of published multidisciplinary literature comprising SoBP. Without their efforts, the organizers would not have been able to focus on the intellectual content and broader impacts of the symposium.

Lastly, we are grateful to the sponsors of the program, especially the NSF Science of Science and Innovation Policy (SciSIP) program for funding our proposal, supporting the vision of dozens of scholars spanning several disciplines to develop a science of broadening participation in STEM fields and the workforce. SciSIP program officer, Maryann Feldman, included our symposium among several agenda-setting workshops for the program. We hope that this report indeed will lead to a focus in the SciSIP program and at NSF more broadly on diversity and inclusion of women, underrepresented minorities, and people with

disabilities in STEM. In addition, we thank George Mason University for the generous sponsorship of the reception following the first day's deliberations. We also thank the Ivan Allen College at the Georgia Institute of Technology for supporting graduate student research assistant Yeong Jae Kim, who helped with background research in preparation of the symposium proposal.

I. Introduction

The need to develop and nurture a diverse and strong science, technology, engineering, and mathematics (STEM) workforce has occupied prominent positions on research and policy agenda in the United States (U.S.) and countries around the world. In the U.S., referring especially to the underrepresentation of minorities, women, and persons with disabilities in STEM, related discussions (and controversies) have turned, on the one hand, on questions of social justice and of equality and equity. However, on the other hand, this situation has been linked directly to issues of economic productivity and growth. The presence of a qualified and agile STEM workforce has long been recognized as central to economic growth (NAS 2007, 2010; Shofer et al. 2000; UNESCO 2010), and the underrepresentation of minorities, women, and the disabled in related fields increasingly has been problematized as wasted resources for building and maintaining a talented and innovative workforce (NAS 2011; UNESCO 2007). In application, such concerns and related debates point to a basic guiding question:

> *How can academic institutions, government agencies, and various businesses appropriately design incentives, opportunities, and organizational structures to engage a diverse group of individuals in STEM for improved productivity and innovation?*

Recognizing the complexity, urgency, and broad significance attending the issues and related matters posed in this question, the National Science Foundation's (NSF) Committee on Equal Opportunities in Science and Engineering proffered a critical and overarching recommendation (CEOSE 2013, p. v):

> NSF should implement a bold new initiative, focused on broadening participation of underrepresented groups in STEM, similar in concept and scale to NSF's centers, that emphasizes institutional transformation and system change; collects and makes accessible longitudinal data; defines clear benchmarks for success; supports the translation, replication, and expansion of successful broadening participation efforts; and provides significant financial support to individuals who represent the very broadened participation that we seek.

The symposium addressed in this report was convened in response to and in the spirit of that recommendation for "a bold new initiative." More specifically, the symposium was convened in recognition of the need for an analytically encompassing and systematically organized approach for understanding and effecting a sustainable broadening participation in STEM fields and the related workforce (Smith-Doerr 2009; Craig-Henderson 2013) – that is, for a *Science of Broadening Participation*.

The Symposium Logic

The Symposium on the Science of Broadening Participation (SoBP) was held 25-26 February 2016 in Arlington, Virginia, organized by Kaye Husbands Fealing, Ph.D., of Georgia Institute of Technology, and Connie L. McNeely, Ph.D., of George Mason University, and

supported by the National Science Foundation's Science of Science and Innovation Policy program.[1] The symposium was convened with the goal of clarifying a vision of the SoBP in STEM and developing research, policy, and action strategies for achieving related goals. In consideration of various stakeholder interests and positions, the symposium was aimed at determining the scope and analytical features of the SoBP and related practice. Bringing together scholars, researchers, practitioners, representatives from funding organizations, and policy analysts with relevant expertise and knowledge, participant invitations rested on identification of experts with a wide range of disciplinary backgrounds engaged in current research, policy, and programmatic efforts addressing issues related to broadening participation and inclusion in STEM fields, especially as pertains to minorities, women, and persons with disabilities. Moreover, explicit efforts were made to achieve diversity in all areas and levels of symposium participation. Owing to the large interest and requests, the organizers opened attendance to 100 experts and other participants, with 75 participants constituting the active core of contributors at any given time, making for encompassing, dynamic, and productive discussions and presentations.

The symposium featured keynote and plenary presentations and panels, moderated "world café" style roundtables, open audience discussions, and structured and unstructured networking, with a reception for general interaction, coordination, and exchanges among the highly diverse group of researchers, practitioners, and decision makers from academia, government, and industry. The first day of the symposium primarily consisted of invited individual and panel presentations and related roundtable discussions, ending with the reception and informal and open interaction. In addition to the keynote and plenary presentations and panels, invited subject matter experts provided directed "flash talks" before each roundtable workshop session, framing pertinent issues and setting the stage for the more extensive and in-depth discussions. The second day also featured invited presentations, and was primarily devoted to group sharing and delineation of action-plans and next steps, including follow-up activities and recommendations for formal SoBP establishment. Notetakers were assigned for each session and presenters also were asked to share their comments and presentation slides when available. (Notes and presentations have been synthesized and incorporated later in this report.)[2]

There were several interrelated objectives underlying and motivating the symposium activities:

- To provide an opportunity for dialogue among from representatives from academia, government, and industry. Provide an opportunity for dialogue between policymakers and researchers to inform the practice of broadening participation in the STEM fields and workforce. Foster a dialogue with practitioners on translating research into strategies for broadening participation.
- To create a forum and (ongoing) teams for sharing and developing interdisciplinary and innovative knowledge, and for determining a roadmap and action agenda with focused solutions for broadening STEM participation.

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[1] Kaye Husbands Fealing, Georgia Institute of Technology, Award # 1551904; Connie L. McNeely, George Mason University, Award # 1551880.

[2] See Appendices for the program agenda and list of participants. For additional information, see the symposium website at http://sobp-conference.weebly.com.

- To explore current cross-disciplinary research that could inform the development of effective intervention strategies. Identify research in social and behavioral sciences and education that exemplify the SoBP. Contribute to the development of a broad research agenda for the SoBP.
- To establish key metrics for evaluating the impacts of diversity interventions.
- To provide guidance for the SoBP by suggesting research questions and areas for study (and identify current gaps). Establish foundations on what was tried, what did not work, what did work, why it worked, and what to do when you know what worked.
- To develop frameworks and roadmaps for increasing representation of underrepresented groups in different sectors.
- To disseminate results, develop models, and prepare recommendations and implementation plans to stakeholder audiences.

In general, the symposium was meant to provide a forum for agenda-setting and advancing understanding and knowledge creation, while promoting SoBP scholarship and collaboration. As such, it offered a platform for considering and developing effective approaches to enhance broadening participation and representation in STEM fields.

Thematic Planning and Arrangement

A Science of Broadening Participation will address perspectives for engaging diversity and participation as both opportunities and resources for advancement, highlighting innovative research and practice in and across STEM education, leadership, and professional arenas in different contexts (cf. Scott and Byrd 2012). Accordingly, symposium tasks included determining the scope and delineating the analytical features of the SoBP and related practices, and considering how the various stakeholders — including those from government, academia, and industry — might come together to establish it in research and application. To that end, the symposium was designed to address seven thematic questions.

1. Why is there a **need** for a *scientific* approach to broadening participation in STEM fields?
2. What are the **frameworks** that *should* inform assessment of underrepresentation relative to employment, education, and policy processes and outcomes?
3. What are the evaluative **measures** that should be used to identify underrepresentation in STEM fields? Is there a need for new data and new metrics?
4. To what extent is **education** both means and ends in STEM participation?
5. How has the U.S. **workforce** been affected by underrepresentation of minorities, women, and people with disabilities?
6. What are the social **implications** of broadening participation in STEM?
7. What are clear **evidence-based pathways** to broadening participation in STEM fields within and across academia, industry, and government?

The basic idea in addressing such questions was to inform research and applied approaches relative to the SoBP for motivating the pursuit of STEM education and training and for removing barriers and improving access to quality education and to occupational opportunity and mobility. That is, the symposium aimed to explore strategies for capacity building and broadening STEM participation. Accordingly, key tasks for symposium

participants included delineating and engaging the SoBP as a critical issue for authentically transformative dialogue and action.

Report Organization

The organization of this report largely reflects the structure and components of the symposium, with particular attention to the aforementioned thematic issues. This introductory part, Section I, offers background information and a general overview describing the symposium purpose and related practical information. The following sections summarize themes, key points, and observations emerging form the workshop, organized topically. Section II reports on comments made about the need for a scientific approach to broadening participation in STEM fields, setting the context for the delineating issues and the relevant deliberations. It is followed by Sections III and IV reporting on the roundtables in which discussions of frameworks and of measures, respectively, guided by the related questions indicated above, took place. Roundtables on education and on workforce issues, as presented in the thematic questions, are then described in Sections V and VI, relating participant discussions and comments. After that, the key points raised in all the roundtable discussions are summarized and highlighted in Section VII. Next presented in Section VIII is a summary of a special panel that considers the implications of a SoBP for what works, especially in reference to questions of accessibility and participation. Section IX presents comments made in special presentations addressing evidence-based pathways to broadening participation in STEM. The report concludes with Section X, which offers closing observations and summative findings with recommendations for next steps and the way forward for the SoBP.

II. The Need for a Science of Broadening Participation in STEM

— Why is there a need for a scientific approach to broadening participation in the STEM fields and workforce?

Although relatively more pronounced in some fields than others, underrepresentation and lack of diversity are noted generally across STEM domains. As reported by NSF (2015), selected minority groups (Blacks, Hispanics, and American Indians and Alaska Natives), women, and persons with disabilities are underrepresented in STEM; they constitute disproportionately smaller percentages of STEM degree recipients and of related employment relative to the U.S. population in general (Ginther et al. 2016). Although some increases have been observed in the STEM participation of underrepresented groups, significant disparities in related educational attainment and employment patterns remain. In general, relative to white students, underrepresented minorities are less likely to graduate from high school, to enroll in college, and to earn a college degree (NSF 2015). Although proportions of bachelor's and master's STEM degrees earned by underrepresented minorities in the U.S. have shown slight increases, their relative share of doctorates has flattened at about 7 percent for the past 10 years. Moreover, as would be expected, these disparities persist as underrepresented students enter the workforce. Minorities and women in general constitute a smaller percentage relative to their proportions of degree attainment. In addition, persons with disabilities — referring to those with "serious functional difficulty" in hearing, vision, cognition, and/or ambulation (Census Bureau 2013) — are underrepresented in the STEM workforce, in comparison to the college-educated population as a whole. Across all groups, more men than women work in STEM occupations.

Calls for a SoBP

Against this educational and employment backdrop, as emphasized in the 2010 reauthorized America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science Act (America COMPETES Act), broadening participation in STEM has become a priority for enhancing the competitive advantage and wellbeing of the United States (U.S.). Still under consideration, COMPETES 2015/2016 also emphasizes broadening STEM participation, indicating the need for programmatic impact assessments and outcomes evaluations, and calling for "a common set of benchmarks and assessment tools to identify best practices" developed or demonstrated by research.

More to the point, as put forward in earlier meetings sponsored by NSF (2008, 2013), there is a critical need for the development and testing of theories for discovering and understanding processes, causes, and consequences associated with broadening participation (Smith-Doerr 2009; Craig-Henderson 2013). In this regard, there is a wealth of theory-driven and applicable research in the social and behavioral sciences and in education that is

especially applicable to the development of a SoBP. Indeed, a burgeoning literature engages questions specifically underlying STEM communities and participation (e.g., Pearson et al. 2015; Drori and Meyer 2006; Fox et al. 2006; Leggon 2006; McNeely and Schintler 2015). In addition, significant research has been conducted on programmatic, policy, and legal interventions expressly aimed at affecting workforce diversity (e.g., Chubin et al. 2015; Curtis and Dreadchslin 2008; DesJardins and McCall 2008; DePass and Chubin 2009; Leggon and Pearson 2008; Goulden et al. 2011; Leggon et al. 2015). Such work has broad implications for improving awareness and understanding of the processes that lead to the inequitable distribution of educational, social, and professional opportunities, and to the subverted productive contributions that could otherwise be made to society. The value added of this work cannot be understated as a foundation for delineating and developing the SoBP. It served as a foundation for much of the related symposium deliberations calling for coherent, consistent, comprehensive, and curated knowledge and data for use in broadening participation in STEM educational attainment and related workforce development and mobility.

Related Plenary Presentations and Panel Discussions

Dr. Jeryl Mumpower, of Texas A&M University and former Division Director of Social and Economic Sciences at the National Science Foundation, offered opening plenary remarks positing the pressing need to broaden participation in the STEM enterprise, emphasizing that broadening participation is not only the right thing to do, in relation to goals of social justice and equity, but that it is the smart thing to do, in relation to goals of productivity and progress. He noted the need for focused and concerted efforts in order to promote evidence-based frameworks and models and to disseminate high quality data and research findings to bring equitable STEM opportunities to all persons regardless of gender, race, ethnicity, or disability status. He charged the group to follow a rigorous inquiry process to determine an action-oriented research agenda to further the goals of SoBP.

In her plenary remarks, **Dr. Heather Metcalf**, of the Association for Women in Science, argued for the need to pursue research and methods informed by critical theory for addressing broadening participation issues. A critical theory approach would help to reveal hidden power arrangements, oppressive practices, and attitudes that must be addressed if positive change is to occur. Metcalf, as did other participants, discussed conceptualizing SoBP relative to ideas of social justice, also in line with Mumpower's points, with critical theory as a means to expose and create space for altering problematic institutional inequities and stratifications. She also offered a critique of the pipeline model that is typically used to explain STEM participation, noting outdated and limited entry points that are no longer consistent with the dynamic nature of education and workforce systems.

Expanding on many of these points and emphasizing the need for rigorous scientific and evidence-based approach to programmatic interventions, **Dr. Hannah Valantine**, Chief Officer for Scientific Workforce Diversity at the National Institutes of Health (NIH), also critiqued the pipeline model, noting the need to design strategies that acknowledge the multi-directional system determining STEM career possibilities. Calling for expanded inquiry and arguing that a "science of diversity research agenda is needed to understand the role and value of workforce diversity in the scientific process, and on its outputs and outcomes,"

Valantine stressed integrating inclusion in policy and practice and promoting the value of diversity in research excellence. She highlighted evidence-based models, such as the "Hubs of Innovation" approach being explored at NIH, which leverages research and evaluation findings, as well as best practices in mentoring, training, and recruitment, to develop an actionable strategy and framework for recruitment and retention of individuals from underrepresented groups at NIH. Invoking lessons learned from existing programs, Valantine delineated a charge for a comprehensive research-centric systems approach to STEM talent recruitment and retention, with the goal of eliminating transition barriers and achieving sustainable transformation in scientific workforce diversity.

In a panel discussion moderated by **Dr. Jong-on Hahm** of George Washington University, **Dr. Ingrid Padilla** of the University of Puerto Rico, Mayagüez, **Dr. Donna Ginther** of the University of Kansas, and **Dr. Cecilia Conrad** of MacArthur Foundation also addressed the need for a scientific approach to broadening participation in the STEM fields and the related workforce. For example, Hahm opened the discussion by noting the need for research translation and the dissemination of successful SoBP models and frameworks into the larger government, academic, and industrial research arena, similar to the translation and transfer of successfully developed technology at publically funded agencies. Padilla pointed out that understanding the complexity of broadening participation requires a multidisciplinary translational approach that considers the interaction of different components and levels of analysis. Calling for further research and assessment in terms of data, processes, and actions, she framed her comments relative to improvement in research tools, feedback, innovation, sustainability, and systems delineation. Adding to this, Ginther advanced that differences in participation must be understood in a frame reflecting "distance from privilege." Referencing her investigation into equitable funding opportunities at NIH revealing significantly differential probabilities in awards by race and ethnicity irrespective of qualifications (Ginther et al. 2016), she posited that the farther participants are from "privilege," the less likely they are to receive funding. Women of color were identified as the farthest from privilege, but they were similarly less likely to receive NIH funding as men of color. Following up on these presentations, Conrad posited "conversations" that must be engaged to develop a SoBP, posing questions on relevant topics:

1. Innovation — Why change? Who needs to change? What needs to change? How can you help the change?
2. Scaling up/replication — How do you design pilots with the greatest possibility of scaling up? How complicated is it? How context dependent is intervention? How should scaling up be effected, via expansion, replication, or collaboration?
3. Communication/framing — How do you translate science so that people understand it and accept it? What messages resonate? How do you motivate people to act?

At the end of her presentation, Conrad conveyed a sense of urgency in the curation of data and transferable knowledge from varied disciplines to effectively broaden participation of underrepresented groups in the STEM fields and workforce.

III. Roundtable Topic 1: Frameworks

— What are the frameworks that should inform assessment of underrepresentation relative to employment, education, and policy processes and outcomes?

Science, as a system of knowledge, thrives on established frameworks, processes, and heuristics for addressing complex problems. As such, the SoBP will turn on a systematic approach to building and organizing knowledge grounded in broadly contextualized rules of research and rigorous methodological critique and application. While there currently is a relative lack of assembled knowledge ready for use for broadening participation in STEM education and the workforce, an institutional and transdisciplinary logic can be invoked as complementary and integrated frameworks for understanding problems, issues, and gaps in knowledge as well as the tools to investigate them in rigorous and replicable ways.

The delineation of theoretical and research frameworks is critical to conceptualizing a Science of Broadening Participation. A framework can represent a conceptual architecture and attention to theory and research on processes affecting STEM participation and performance is of particular importance in curating knowledge from various areas of study related to assessing causes of underrepresentation in STEM fields. Thus, for example, issues such as identity, stereotypes, bias, and interventions might be identified as key research areas in this regard. In this sense, a framework also provides an overview of interlinked factors that support approaches to achieve a specific objective, specifying dimensions for understanding related analytical domains. Framework components might include, for example, scope, objective contexts, ontologies, principles, processes, and procedures. As such, a framework provides analytical guidance and may be modified as needed relative to various intra- and inter-dependencies among relevant components (Kuiler 2016).

As a critical activity for SoBP development, symposium participants were invited to consider both new and existing frameworks to support a scientific approach to further understanding and informing assessments of participation and inclusion relative to STEM employment, education, and policy processes and outcomes.

The Thematic Charge

Remarks by **Dr. Amanda Bayer**, of Swarthmore College, emphasized rigorous and evidence-based frameworks. Pointing to the scientific and transdisciplinary goals associated with the SoBP, she called for finding common ground in the shared norms and language of science. Moreover, she discussed the need for engaging and developing frameworks that combine both top-down and bottom-up approaches and that address both supply and demand side factors to affect diversity and representation in STEM. Bayer suggested targeting issues such as bias, outreach, pedagogy, mindsets, and the like, as critical treatment areas for the SoBP, and looking to questions about the benefits of diversity in various forms and in various contexts.

Roundtable Guidelines

Additionally, as an initiating suggestion, frameworks roundtable participants were advised that the discussion might include exploring models for increasing the supply of qualified STEM workers and professionals, advancing productive relationships and engagement, and identifying opportunities for motivating inclusivity and participation. Broad and/or specific topics might be addressed, including the following issues and directions:

- Curating existing research and knowledge from various areas of study related to understanding and assessing underrepresentation in STEM fields.
- Theory and research on processes affecting performance.
- Identity, stereotypes, bias, and intervention research.
- Governance structures.
- Community dynamics and relations.
- Organizational dimensions.

Roundtable Discussions

A common theme emerging from the frameworks roundtable discussions was the establishment of SoBP as a system, and the potential of using complex systems research and analytical methods to further interrogate racial, ethnic, gender, and disability disparities in STEM fields. Participants described studies that could elucidate systems dynamics and actor relations and considered how such studies could shed light on related inefficiencies for broadening participation. Such studies were proposed as starting points for suggesting and delineating interventions to address disparities in STEM participation. The recognition of SoBP as a system was also related to sentiments expressed by some participants that SoBP should seek to build on existing frameworks, rather than looking to entirely new models.

However, other participants also considered how new frameworks emerge or are implemented, while emphasizing the need for incremental and bottom-up approaches that seek larger community engagement and buy-in for program planning and outreach initiatives. Consistent with the research base regarding STEM participation among underrepresented groups,[3] participants emphasized that minority students often view their identity as intertwined with the larger community. Thus, for example, while traditional academic research rewards publications in high impact journals and forward citations, some underrepresented students might also view success in terms of family and community impact, highlighting a need for broader or more encompassing STEM incentive frameworks. Recommendations were made for outreach that frames STEM education and careers as opportunities to solve basic community problems. Examples were offered in which an outreach program might demonstrate how chemists, hydrologists, and environmental scientists protect or provide potable water supplies, while another outreach program might highlight the role of technology and computer science in supporting health and accessibility research for physical disabilities.

[3] E.g., see references in NAS (2011).

Arguments were offered to the effect that, by recognizing varied perspectives, applied frameworks could be more responsive to the needs of different groups by incorporating their experiences and backgrounds into interventions. In this sense, frameworks also could be more reciprocal, i.e., by seeing researchers and institutions as a part of the same community and encouraging shared learning. The Social Justice Institute in Action was offered as another example of a community-based, participatory approach to research. Such ties to community also meant that frameworks would be informed by environment and context, which arguably is key in recruiting and retaining talented students and workers.

Discussion focused on the need for frameworks that are more robust and inclusive. At a basic level, as mentioned, frameworks should be more inclusive of the goals and motivations of targeted groups. There also was discussion of STEM within government and industry sectors as well as academia, and suggestions that analytical and intervention frameworks should be mindful of varied environments. Furthermore, participants emphasized distinctions between diversity and inclusion concepts in research and policy development, with diversity viewed more as a "check the box" idea based on simple numbers of persons and inclusion viewed more broadly in terms of quality of interaction and intentional recruitment and retention of underrepresented persons

Several participants raised examples of frameworks and programs that might have potential if brought to scale. One challenge that was identified was the lack of communication among disciplines and communities of practice, and resulting redundancy and overlap in efforts and delivery. Also emphasized was the need for a better inventory of evidence to support bringing successful interventions to scale.

IV. Roundtable Topic 2: Measures

— What are the evaluative measures that should be used to identify underrepresentation in STEM fields?

Evaluation and metrics are central to conducting scientific research and to determining the applicability and value of a given approach. Accordingly, identifying and developing valid and relevant metrics and tools for research and assessment are fundamental tasks for establishing a Science of Broadening Participation. Metrics of and for change identification, monitoring, and evaluation are of particular importance in this regard.

Measurement, encompassing basic data collection to complex indicators and analytical performance, provides the foundation for understanding any problem, program, intervention, or initiative. Reliable and relevant data are crucial to all steps of the scientific inquiry process, from research question and hypothesis formulation to experimentation and reporting. Accordingly, a symposium goal was to encourage participants to probe existing data that might be leveraged to capture and understand underrepresentation and related processes in STEM fields, as well as to address the limitations of those data. Participants also discussed data needs for rigorous SoBP assessment.

That is, as a critical activity in SoBP development, symposium participants were invited to address questions about evaluative measures for identifying and studying participation and inclusion, along with various related issues, in STEM, and to consider the need for new data and new metrics and their broader impact and analytical engagement.

The Thematic Charge

Remarks by **Dr. Donna Ginther**, of the University of Kansas, offered a foundation for roundtable discussions on measures for SoBP use. Using her own research as an illustration, Ginther outlined the integral role of data for SoBP delineation and conduct. She referenced her investigation into the likelihood of receiving research funding from NIH relative to race and gender identification, with findings indicating that, irrespective of qualifications, underrepresented minority and women researchers were less likely to receive funding and less likely to submit multiple funding applications than their white male counterparts (Ginther et al. 2016). Moreover, noting that her research engaged only quantitative data, Ginther suggested that the study also would have benefitted from the incorporation of qualitative data to provide a more in-depth contextual understanding of the findings and fuller explanations in areas where the quantitative measures fell short. Ginther also emphasized the general role and use of data in identifying gaps in understanding and the need for better data and measures whereby researchers and decision-makers can better engage interventions and research agendas to address those gaps.

Roundtable Guidelines

As an initiating suggestion, measures roundtable participants were advised that the discussion might include identifying and exploring data and measures for operationalizing and evaluating models for increasing the supply of qualified STEM workers and professionals, advancing productive relationships and engagement, and identifying opportunities for motivating inclusivity and participation. Broad and/or specific topics might be addressed, including the following issues and directions:

- Curating existing data and knowledge from various areas of study related to assessing underrepresentation in STEM fields.
- Identifying and developing specifically SoBP metrics and tools for research and assessment.
- Considering data availability and needs.
- Contextual implications of various metrics and data.
- Metrics of and for relational transformation.
- Identification, monitoring, and evaluation.

Roundtable Discussions

A key point raised by roundtable participants was the limitations and politics of data access, particularly when working with potentially sensitive variables like disability status and race/ethnicity categories. The first part of the data access equation is related to the legality of collecting certain variables. Many participants echoed legal or policy-related limitations in accessing data segmented by race/ethnicity and disability status. When collecting student data, for example, particularly at the K-12 level, participants shared experiences in which schools were not permitted to share these types of demographic variables at disaggregated levels. Such limitations make micro-level or longitudinal studies nearly impossible in the absence of onerous data use agreements and formalized memoranda of understanding. Moreover, participants pointed out that disabled persons or persons belonging to minority groups may be hesitant to list their status, due to distrust in the purposes and how related data might be used, resulting in incomplete or inaccurate datasets.

Several participants also identified the siloed nature of some datasets as a limitation in effectively measuring issues of STEM participation. The wide ranging implications of a homogenous STEM enterprise leads many researchers to require data from disparate sources to answer research questions and assess STEM participation. Thus, for example, researchers in this area often incorporate data from both employment and education sources, as well as drawing upon more unique data such as funding and research outcomes, participation in various programs, and environmental data. Also, researchers often seek to draw comparisons across institutions, fields, and local, regional, and national contexts. Participants noted that data sources and measures often are quite disparate, adding additional complexities to cross-cutting analyses. Some participants suggested developing a set of data collection and use standards to improve the comparability of data sources most commonly used in STEM disparities research.

When discussing the politics of data access, participants noted that restrictive gatekeeping of data sources presented limitations to studying questions of representation in STEM. Entities such as the Department of Education and the National Science Foundation are viewed as the gatekeepers of educational and academic data in the U.S. While both agencies have a wealth of publically available data for researchers, these data often lack the granularity, particularly in traditional demographic variables, required to support robust analyses of STEM participation. Though it is not impossible to receive special access to restricted use datasets containing the required data, the process often involves lengthy request and justification paperwork and a turnaround time which may be incompatible with research and publication timelines.

Attention also was given to the actual measures and variables derived from collected data. Some participants criticized current measures as too transactional or output focused, with little attention paid to outcomes, impacts, and more abstract ideas. Participants identified a need for coherent measures aimed at assessing the quality, rather than only the quantity, of STEM participation and representation. Many participants noted that funding agencies, such as NSF, should consider supporting studies similar to Ginther's analysis of representation in NIH awards. Some existing data also reflect limited or exclusive measures of STEM fields and STEM workers, which can lead to skewed findings and inequitable recommendations. For example, technicians — usually in computing — often are left out of STEM workforce measures because they do not possess related educational degrees that are used to define the field. Depending on purpose, such classifying practices also may provide a poor basis for assessments of actual day-to-day work and, therefore, incomplete or inaccurate representations of STEM workers and participation.

Roundtable participants also discussed the tension that sometimes exists between qualitative and quantitative measures, and attendant researcher attitudes. Although the two types of measures can be engaged together to provide more complete and robust pictures of STEM representation, quantitative measures often are privileged, with claims of greater rigor and trustworthiness by domain scientists. Related narrow views impose limitations on understanding and research possibilities. Furthermore, participants noted that certain measures, such as self-efficacy, sense of belonging, and the impact of socialization, are better measured through qualitative means.

In addition, a topic that had some prominence in the discussion of metrics involved indicators of diversity and diversity impacts and related processes in academia, government, and industry. While important research exists showing the value added and effectiveness of diverse research and management teams (e.g., Herring 2009; Hunt et al. 2016), participants suggested that there typically are insufficient measures and data available to truly assess diverse teams and the impact of diversity on related productivity efforts. Participants called for the development of improved data and measures for assessing the value of diversity as a critical component of the SoBP.

Also expressed was a need for both top-down and bottom-up approaches in research and policy development, with participants stressing the coupling of top-down and bottom-up interventions for effecting cultural change within institutions to support diversity and inclusion goals.

V. Roundtable Topic 3: Education

— To what extent is education both means and ends in STEM participation?

The Science of Broadening Participation encompasses education as both means and ends for success in STEM educational attainment, disciplinary community building and networks, and related workforce access and mobility. A wide range of research has investigated relevant processes and effects in education itself as a social institution (Cuban and Shipps 2000; Frank and Meyer 2007; Gumport 2007; Hallinan 2000; Hallinan et al. 2003; Snyder 1999; Lloyd-Jones 2009), with extended attention to the disabled along with other underrepresented groups (Hehir 2002; Spencer and Romero 2008). Indeed, taking education seriously as a social institution, its role in society reflects a variety of purposes beyond the basic instruction, training, and knowledge diffusion function. They include, for example, socialization, certification, and sorting and selection (Ballantine and Hammack 2011). In terms of socialization, schools help to produce individuals equipped with attitudes, values, and skills needed for the performance of social roles and take their place in their communities and society more generally. Certification refers to bestowing credentials that are accepted as evidence of having met some set of requirements and level of competence. Moreover, schools are mechanisms for sorting and selection, determining access to subsequent educational, occupational, and social positions and opportunities. While, in practice, a great deal of variation can attend such purposes, they form the foundation for assessing the meaning, impact, and role of education as means and ends in related processes. This point is born out in theory and research on educational attainment in general and more specifically in relation to stratification and status attainment.

Given this understanding relative to SoBP, symposium participants were asked to consider issues regarding contextualizing educational access, opportunities, and outcomes and their broader implications for STEM participation and success. Expanding on topics raised in discussions about frameworks and measures, participants were charged with discussing issues of broadening participation in the education pipeline, including pedagogy, access and barriers in pursuing STEM education, trends in representation, and improving educational outcomes for students from underrepresented groups.

The Thematic Charge

Dr. Gertrude Fraser, of the University of Virginia, offered the opening remarks for the education thematic roundtables. In doing so, Fraser expressed the need for new educational paradigms, reminding symposium participants of the purposes of the current system, initially developed during the Industrial Revolution and based on standardization and hierarchy. Emphasizing different means for different ends, Fraser called for more dynamic, inclusive paradigms and for new approaches to pedagogy to support attainment of 21st century skills and to encourage a more diverse STEM pipeline. She argued that resistance to change is related to epistemic and relational motives and less so on matters of fact and rationality.

Accordingly, she encouraged engaging in strategic dialogue to identify shared reality and affiliative motives to create consensus about content and directions of change. She stressed the need for a dynamic, changing, and contingent education built for inclusion-disruptive technologies and characterized by open knowledge and open access approaches.

Roundtable Guidelines

Education roundtable participants were advised that discussion might include identifying and exploring educational approaches and models for increasing the supply of qualified STEM workers and professionals, advancing productive relationships and engagement, and identifying opportunities for motivating inclusivity and participation. Broad and/or specific topics might be addressed, including the following issues and directions:

- Curating existing research and knowledge from various areas of study for assessing educational attainment and underrepresentation in STEM fields.
- Contextualizing educational access, opportunities, and outcomes and their broader implications for STEM participation and success.
- Identifying critical issues and areas for directed SoBP study.
- Theory and research on processes affecting performance and achievement outcomes.
- Studies of academic choices and outcomes.

Roundtable Discussions

As in other roundtable discussions, several participants noted the complexity attending systems of STEM education. STEM education often carries broad definitions and, in practice, might also be affected by, for example, other issues such as nutrition, healthcare, and parental employment as key determinants. Some participants noted the need for more intentional, reinforcing interactions among system actors in order to provide the social supports needed to support academic success for students. Many highlighted the lack of social support and of social safety net programs as detrimental to students beginning at the earliest points of the STEM pipeline. Some roundtable participants also highlighted increasing gentrification as a problem, noting as well that high quality teachers usually are assigned to schools in higher socio-economic status districts, while schools in depressed areas are left further underserved.

Some participants raised questions about the responsibility that educators and researchers, at all levels, should assume in recruiting and retaining underrepresented groups in STEM fields. Noting that physicians, for example, often perform community service either providing pro-bono work in local clinics or serving as role models and mentors for children, participants discussed what a similar program might look like for STEM faculty or practitioners. This discussion echoed ideas raised by Dr. Fraser, who noted that underrepresented groups may struggle to visualize themselves as "scientists" or "engineers" and, therefore, could benefit from interacting with mentors and role models from their communities. However, some participants also noted that colleges and universities often do not value service to any great

degree, making it difficult to incentivize faculty and researchers to engage in such outreach. This was seen as a further institutional barrier to efforts to broaden participation in STEM.

Along the same lines, participants noted a lack of attention to pedagogy and teaching philosophy, especially at the post-secondary level. Faculty often are held accountable only for research outcomes, with teaching treated essentially as an after-thought. Participants discussed the need to incentivize and reward faculty for effective teaching as well as for mentoring activities and service in the university and in the community. Related to pedagogy and classroom engagement, some participants argued that, in general but particularly when teaching first-generation and other underrepresented students, it is key that faculty and educators demystify the ivory tower, calling for clear articulation of learning goals and measures of success, making expectations transparent. This kind of clarity can help to raise student confidence and remove confusing and unnecessary barriers to learning and classroom success. Participants also discussed the critical need for training to address biases in the classroom, both among educators and students.

Related to discussions regarding community participation for recruitment and retention of students from underrepresented groups, roundtable participants again noted the need to establish STEM participation as an aspiration by promoting visible role models and framing STEM knowledge for solving practical problems. One programmatic example offered during roundtable discussions that actively took community conditions into consideration was the University of Texas system's 2+2 Program, in which students complete the first two year in a community college, transferring to a University of Texas campus for their junior and senior years. This program sought to improve enrollment of minority students by leveraging the fact that first-generation and minority students often pursue education at community colleges at a disproportionately higher rate compared to their white peers. Participants posited that such programs were relatively successful because the underpinning frameworks were informed by data on student behavior and communities and in recognition of associated student goals and motivations.

Participants also discussed the role of STEM education as broader than simply teaching chemistry or mathematics concepts. For example, the scientific inquiry process can teach critical thinking and self-efficacy for students, even if they do not pursue STEM careers. Such learning opportunities provide further incentives to ensure STEM outreach is present in typically underserved communities. Focusing on these kinds of indirect outcomes of STEM education also supports arguments for earlier points of entry for STEM learning in the education pipeline. For example, while a kindergartener might not be ready to learn about physics as such, they may be prepared to learn about the general scientific inquiry process.

Furthermore, in consideration of some of the unique aspects of STEM education compared to other fields, participants discussed issues of accessibility, particularly in the laboratory environment. While policies and laws, such as the 1990 Americans with Disabilities Act, offer protections for persons with certain disabilities, participants questioned the extent to which related provisions were followed or applicable in laboratories and if proper accommodations were always made. Participants also discussed the extent to which some educators might view making accommodations as an unfunded mandate, and how these attitudes might affect students with disabilities. Referencing the panel on "What Works:

Dimensions of Accessibility and Participation" (see Section VIII of this report), some participants offered suggestions such as separate surveys and studies to assess this issue and to understand the role that physical disabilities might play for recruitment and retention in STEM fields.

VI. Roundtable Topic 4: Workforce

— How has the U.S. workforce been affected by underrepresentation of minorities, women, and people with disabilities?

The disproportionately low representation and participation of minorities, women, and persons with disabilities in the STEM workforce are the result of complex and systemic institutionalized processes. Lack of diversity and participation in STEM across academia, government, and industry employment sectors is an expression of processes reflecting broad societal dynamics and relations; i.e., underrepresentation of particular individuals and groups has resulted from hierarchical relations and social and institutional barriers to occupational opportunity and access. Such processes have been explored in interrelated research not only on educational attainment and work requirements, but also on, for example, social stratification and inequality in terms of race, class, gender, disability, and other markers of social differentiation and societal hierarchy (e.g., Grusky 2014), discrimination, bias, and "chilly-climate" in the workplace (Turner et al. 1999; Coates 2012; Sue 2010a,b), occupational mobility and leadership (Byrd 2009; Meyer 2013; Parker 2005; Schein 1992), organizational environments (Greenwood et al. 2008; Suddaby et al. 2010), and workplace culture and diversity (Pless and Maak 2004; Scott 2010; Scott and Byrd 2012). Also, various workforce projection studies have been conducted incorporating discussions of diversity and participation across groups and sectors, including preference and confidence effects (Sax 1994, 2012; Toossi 2006; Scott et al. 2011). In addition, research has been conducted on programmatic, policy, and legal interventions expressly aimed at affecting workforce diversity (e.g., Chubin et al. 2015; Curtis and Dreadchslin 2008; DesJardins and McCall 2008; DePass and Chubin 2009; Leggon and Pearson 2008; Goulden et al. 2011; Leggon et al. 2015). There remains a critical need for more research on the value and relationship of workforce diversity for obtaining competitive advantages and progress and, among others, the issues listed here are central to understanding STEM workforce dimensions and dynamics.

In light of SoBP relevance, symposium participants were asked to consider such issues as means for contextualizing STEM occupational access, opportunities, and outcomes. Principal tasks included investigating recruitment and retention issues in STEM and related occupational fields and examining motivation and mobility in different sectors, professional networks, and organizational and institutional change.

The Thematic Charge

Dr. Roli Varma, of the University of Virginia, opened the workforce roundtables with remarks calling for defining the STEM workforce and delineating what constitutes a STEM worker. She discussed related careers, pointing out that persons with STEM degrees might follow a variety of occupational pathways, including those that may not be traditionally defined as STEM fields. Noting that the increased focus on STEM careers reflects expected growth in STEM employment, Varma reported projections as high as 18.7% growth over

the next ten years. Projections also show that this workforce remains overwhelmingly white and male. Varma noted that, while minorities and women may not be explicitly barred from entering STEM fields, cultural and institutional biases make their retention and experience undesirable. She indicated that, while laws exist to address disparities in, for example, salaries and resources, implementation is lacking. She suggested that government could take action to address such distributional issues.

Roundtable Guidelines

Workforce roundtable participants were advised that discussion might include exploring approaches and models for increasing the supply of qualified STEM workers and professionals, advancing productive relationships and engagement, and identifying opportunities for motivating inclusivity and participation within and across academia, government, and industry. Broad and/or specific topics might be addressed, including the following issues and directions:

- Curating existing research and knowledge from various areas of study for assessing underrepresentation in the STEM workforce.
- Identifying workforce dimensions and dynamics.
- Delineating implications and broader impact of underrepresentation.
- Contextualizing occupational access, opportunities, and outcomes.
- Investigating recruitment and retention issues in STEM and related occupational fields.
- Examining motivation and mobility within and across different sectors.
- Characterizing professional networks and cultures.
- Investigating organizational and institutional change.

Roundtable Discussions

Roundtable participants considered the role of SoBP research and policy analysis in supporting a more diverse and inclusive STEM workforce. It was noted that there was a tendency in discussions of the STEM workforce to assume reference to related degree holders. However, caution was called for in related specifications in light the wide availability of STEM jobs with different educational and certification requirements. For example, the need for technicians has been cited in several related areas, such that STEM workforce delineations must be adjusted accordingly.

Participants debated the presence of shortages in supply and demand shortages relative to developing a robust and inclusive STEM workforce. Some participants argued that U.S. post-secondary institutions were failing in producing a diverse pool of STEM graduates, while others contended that U.S. industries preferred to hire international STEM graduates rather than domestic underrepresented students. There was a general agreement that improved data and more analyses were needed to fully understand the underlying issues and inefficiencies in the STEM workforce relative to diversity.

Also in regard to supply and demand, a closer relationship among academia, government, and industry partners was suggested to better align STEM curricula with changing workforce needs. These partnerships might also involve more development and training in "soft skills" such as project management, collaboration, and effective writing.

Questions of implicit bias also received a great deal of attention in the roundtables. Considering programmatic approaches for dealing with bias, discussion referenced Dr. Valantine's mention of ongoing pilot studies at NIH to assess the impact of implicit bias in review processes, making special note of the Stadtman Investigators Search, a trans-NIH effort to attract a diverse group of talented early-career scientists pursuing interests across biomedical fields. This pilot program seeks to address bias through blind reviews and baseline assessments and attitudinal tests. Also discussed was implicit bias that reached beyond demographic factors to include, for example, biases based on institutions. In this case, one applicant may be judged more favorably if they trained at a prestigious institution. Along these lines, participants discussed the issue that some reviewers may not see Minority Serving Institutions as competitive and, therefore, may not score applications from them as highly as others, irrespective of proposal quality.

Some participants, citing Dr. Varma's comments, pointed to antiquated policies and rigid systems, e.g., in issues of family care, as causes for women's underrepresentation in STEM in academia. Also related to academic work, implicit and other biases were discussed as limiting equitable opportunities in tenure, promotion, publishing, and funding practices. Apart from immediate term impacts of such biases, effects are compounded when underrepresented groups are denied career advancement due to lacking publication or funding portfolios. Dr. Metcalf's earlier remarks also were invoked in these discussions, with research findings and data showing growing disparities along career trajectories. Even in fields in which women and other underrepresented groups are near parity in degree attainment, large disparities still exist among tenured faculty and leadership. Participants also noted increased bias with more homogeneous leadership profiles.

VII. Roundtable Highlights

The symposium was aimed at understanding, developing, and engaging a Science of Broadening Participation for expanding representation and inclusion in the STEM fields and workforce. To that end, roundtable participants were asked to determine and consider principal issues, challenges, and approaches that could be used to address questions about engaging diversity and participation as both opportunities and resources for advancement and productivity, highlighting relevant and innovative research and practice. The roundtables joined together cross-institutional and multi-disciplinary groups of experts — including academic faculty and researchers, government employees, college and university administrators, members of industry, and researchers and analysts from think tanks, professional organizations, and other entities — in action-oriented dialogue to address issues of broadening participation and to work toward establishing sustainable, action-oriented research and policy agendas for bringing equitable representation to all aspects of the STEM enterprise.

Key Roundtable Points

- Successful frameworks for understanding and assessing STEM participation should be inclusive of stakeholder input, consider the goals and motivations of different groups, including underrepresented students and workers, and be powered by data measuring related behaviors and outcomes.
- More high quality longitudinal studies and data on participation and inclusion are needed in direct engagement and development of a SoBP.
- New and better contextualized models of STEM participation and inclusion are needed, and should be central to SoBP practice.
- A need exists for both top-down and bottom-up approaches in research and policy development, with applications stressing the coupling of top-down and bottom-up interventions for effecting cultural change within institutions to support diversity and inclusion goals.
- Applied, community-oriented research might be more aligned with goals and motivations of students from the targeted groups, and might better inform policies and programs for encouraging broader recruitment and retention in STEM education and later in the related workforce.
- SoBP and STEM researchers, educators, and practitioners should engage with and draw from local and other relevant communities as role models and mentors, through both formal and informal outreach and partnership initiatives.
- The SoBP community should leverage systems approaches and research methods to examine the extent to which a SoBP system exists, and how the systems framework can support researchers in identifying and assessing disparities in STEM participation.

- The development and dissemination of data collection, sharing, and use standards would facilitate inter-institution, inter-field, and international research in support of SoBP goals.
- Possibilities for blanket restricted data use agreements across data collection entities should be explored and pursued, as appropriate, to facilitate relevant research.
- Educational paradigms and pedagogical approaches need to be refreshed in light of new and evidence-based methods (e.g., growth mindset approaches to problem solving).
- There is a need to "demystify the ivory tower" and to make expectations and evaluation criteria transparent to students to support recruitment and retention in the STEM pipeline.
- An inventory of successful interventions should be conducted (and updated and maintained) to support SoBP and work to bring successful programs to scale.
- Promotion of more academia-industry-government partnerships should be pursued to keep STEM curricula and workforce needs in close alignment.
- Distinctions between diversity and inclusion must be understood in research and policy development, with diversity viewed more as a "check the box" idea based on simple numbers of persons and inclusion viewed more broadly in terms of quality of interaction and intentional recruitment and retention of underrepresented persons.
- Increased and improved training is needed to recognize and address bias, particularly implicit bias, at all points and at all levels of the STEM pipeline.
- Sustainability and the "normalization" of diversity must remain central to SoBP research and policy agendas.
- Evidence shows that diversity leads to better science and is correlated with increased productivity and positive performance. The onus should be put on skeptics; let the burden of proof be on those who argue that diversity impedes excellence in STEM.

VIII. Implications for What Works

— What are the social implications of broadening participation in STEM?

As previously mentioned, a principal aim of the symposium was to explore strategies for capacity building and broadening STEM participation, especially as regards underrepresented minorities, women, and persons with disabilities. On the one hand, selected policies and interventions have been identified as having some success in increasing educational attainment and professional access and mobility for the groups in question (Chubin et al. 2015; Leggon et al. 2015; Leggon and Pearson 2008). However, on the other hand, research has shown that many conventional approaches and assumptions about related problems do not lead to the encompassing or sustainable changes necessary to effect inclusion and positive transformation. For example, assertiveness training does not improve women's ability to negotiate (Babcock 2003, 2005, 2007); "colorblind" approaches to racial attitude interventions are less effective in reducing bias than those with explicit reference to prejudice (e.g., Richeson and Nussbaum 2003); "diversity training" does not lead to greater diversity in upper management in corporations (Dobbin et al. 2011); "diversity professionals" training is generally ineffective (Kalev et al. 2012); and successful diversity initiatives in one field can have unintended negative effects in others (Myers and Fealing 2012; Fealing et al. 2015).

Recognizing that the relevant processes, structures, and relationships are deeply institutionalized and culturally enduring, finding ways to disrupt such patterns remains a critical task for STEM development and expansion, and the need to do so is more politically, socially, and economically urgent than ever before.

Related Panel Discussion

To explore related issues, the symposium included a special panel on "What Works: Dimensions of Accessibility and Participation." The panelists discussed concrete examples of promising programs and interventions, drawing lessons and considering their implications for social wellbeing and broadening the participation and inclusion in STEM of minorities, women, and persons with disabilities. The panel moderator, **Dr. Paul M.A. Baker** of Georgia Institute of Technology, framed the discussion, noting that "inclusion, though wonderful, does not operate in a vacuum" and charging participants with the "responsibility to anticipate and design for effective, successful inclusivity." He further added to arguments positing the need for evidence-based policies and programs, with particular emphasis on three broad issues:

- facilitating "universally designed" institutional cultures.
- innovative preparation and workforce development, with an eye to matching skills to organizational needs and future labor demands.
- openness, innovation, and creativity as central tenets of diversity and inclusivity.

Expanding upon these points, **Dr. Mary Ann Leung**, of Sustainable Horizons Institute, described a model and multi-dimensional approach for developing STEM educational and training programs and for supporting early career professionals through mentorship, career guidance, and leadership development. In that regard, she offered various practical "governing principles" for program development and effectiveness:

- coupling interventions with research to inform each other.
- developing sustainable pathways.
- mainstreaming across sectors.
- fostering and engaging community.
- normalizing inclusion.

She also argued that, rather than offering them as episodic events, the most effective programs provide continuous scaffolding and support, and that broadening participation ultimately requires a systemic approach aimed at transforming the cultural landscape such that inclusion becomes the norm.

Tamitha C. Tidwell, of the University of Washington, focused on evidence-based practices developed with input from persons with disabilities, suggestions from practitioners, ongoing formative evaluations, relevant research, and other project outcomes. Noting that accommodations for disabled persons can be even more problematic as they leave the K-12 education environment, when parents and guardians are no longer present to advocate for children, Tidwell considered the role of technology in both increasing and limiting accessibility. Particular emphasis was placed on the promotion of self-determination — i.e., the ability to set and reach goals — requiring relevant knowledge, skills, and belief in individual capabilities. Describing projects and work at the University of Washington, she noted that the most effective practices combined efforts to prepare students for STEM academic and workforce transitions, ensure technology access and effective use, and provide peer and mentor support. Success for individuals was noted along four dimensions: (1) a sense of belonging (academic and social integration); (2) involvement (in academic and social life); (3) a sense of purpose (through internships, workshops, networking, mentoring, etc.); and (4) self-determination skills (practice, skill building, etc.). Moreover, she stressed the importance of tracking and longitudinal studies for gathering evidence and gauging success.

Dr. Emorcia Hill, of Harvard University, noted that the establishment of a Science of Broadening Participation is predicated on mainstreaming issues of diversity and inclusion, moving from the periphery of institutional policies, practices, and programs, to the center as fundamental considerations. Calling for new SoBP frameworks and paradigms, Hill posited three principal approaches for framing the related dialogue:

- producing usable knowledge and evidence that can be robustly and rigorously applied to create and sustain a SoBP.
- identifying strategies and methods to formulate salient questions and to interrogate the conceptual, methodological, analytical and translational frameworks for a viable and visible SoBP.

- establishing an engaged community of scholars who subscribe to the fundamental principles and edicts of the SoBP and find ways to operationalize related values.

Expanding upon these approaches, she delineated necessary elements that must be addressed to establish a science as such, including basic elements, evidence dimensions, scope conditions, and resources. Throughout her presentation, Hill's comments echoed the basic premise and goal to establish convincingly, through the generation and production of rigorous scientific evidence, that broadening participation, as greater inclusion, adds meaningful contributions and value to the attainment of organizational missions and, by extension, productivity and competitiveness for the country as a whole.

IX. Pathways to Broadening Participation in STEM

— What are clear evidence-based pathways to broadening participation in STEM fields within and across academia, industry, and government?

While the symposium focus was on the principal and overriding categories of underrepresented minorities, women, and persons with disabilities, SoBP applies to diversity in its many forms, with a focus on developing and leveraging workforce diversity for broader inclusion and transformation. Indeed, leveraging diversity refers largely to strategic approaches for various ends (cf. Scott and Byrd 2012; Scott 2010):

- adapting to and managing change based on demographic shifts.
- enhancing disciplinary and professional cultures that embrace broadening participation.
- advocating and developing policies and practices that support inclusion and diversity.
- increasing productivity and institutional efficacy to obtain growth and advancement.

Accordingly, a wide range of research has been conducted on programmatic, policy, and legal interventions expressly aimed at affecting STEM education and workforce diversity (e.g., Chubin et al. 2015; Curtis and Dreadchslin 2008; DesJardins and McCall 2008; DePass and Chubin 2009; Leggon and Pearson 2008; Goulden et al. 2011; Leggon et al. 2015). Encompassing related issues, a SoBP will offer pragmatic and grounded pathways to determine evidence for informing efforts to broaden participation, reflecting specific characteristics (cf. Smith-Doerr 2009):

- It will document the distribution of relevant educational and economic opportunities.
- It will include analyses of behavior and effects among different groups and at different scales and levels of analysis (e.g., individual, group, societal).
- It will be inherently interdisciplinary.
- It will foster collaboration and productivity among social, behavioral, natural, and physical scientists engaged in broadening participation efforts.
- It will be methodologically rigorous and will incorporate research based on a variety of empirical approaches and techniques.
- It will be theory-driven, informed by, grounded in, building upon, or challenging extant social, behavioral, and educational approaches.

As such, a SoBP will provide evidence-based pathways to broadening participation and inclusion in STEM. The research itself will be conducted to determine what works and what is needed to broaden participation and effect diversity, with the goal of informing the development of relevant policies, programs, initiatives, and interventions. Indeed, a basic task for the symposium was process delineation and identification of intervention research

and applications, aimed at developing innovative pathways toward new theories, practices, and metrics for broadening participation and representation in STEM.

Related Topic Presentations

Bill Valdez, of Consultants International Group, expanded on the systemic nature of underrepresentation in STEM and related implications. Noting overall system inertia, he emphasized the need for frameworks and longitudinal and incremental approaches to undermine and disrupt the complex processes by which underrepresentation and exclusion are maintained. He argued that, in practical terms, interventions designed to improve the STEM system must be focused on short-term wins and long-term change. Noting its disproportionate impact on broadening participation through funding, policies, and programs, his comments were focused especially on the federal government. Valdez noted that the federal scientific community remains to be convinced fully of the value and need for SoBP. To that end, he offered various action strategies as pathways and means for effective change and engagement:

- Link SoBP efforts explicitly to mission statements and organizational performance goals.
- Link SoBP efforts to organizational and mission benefits and accomplishments.
- Provide evidence of the positive impact of broadening participation.
- Engage in the political processes and apply political pressure to obtain leadership buy-in and institutional commitment to broadening participation.
- Strengthen the community of practice.
- Link and coordinate broadening participation initiatives and efforts.
- Build a coordinated, multi-nodal research and policy network across sectors.
- Work with NSF's programs for broadening participation.
- Create a strong SoBP research base, focusing on the tools, methods and data needed to influence federal programs and policies.

Dr. Krishna Athreya, of Iowa State University and the Committee on Opportunities in Science for the American Association for the Advancement of Science, also offered remarks echoing the need for a systems approach to broadening participation. Moreover, she argued for a more explicitly contextualized perspective on SoBP, noting that none of the SoBP system actors should be analyzed as standalone entities or as occurring in a vacuum. Emphasizing the institutional, cultural, and political contexts in which participation and success are determined, she issued a call for a fuller understanding of the dynamics and interactions within the system that ultimately designate and define representation and inclusion in STEM.

X. Conclusion

—What is the research agenda for the Science of Broadening Participation?

Necessary for positive change and building a qualified and sustainable STEM workforce is a Science of Broadening Participation (SoBP), an assembled and curated body of knowledge ready for use for broadening participation in STEM education and the STEM workforce. While a large and rich body of research exists relevant to this issue, related policy and programmatic efforts have faced a variety of challenges that reflect fundamental research questions and applications in the SoBP.

The Symposium on the Science of Broadening Participation brought together scholars, researchers, practitioners, representatives from funding organizations, and policy analysts with relevant expertise and knowledge to determine the scope and analytical features of the SoBP and related practice. In consideration of various stakeholder interests and positions, an important symposium goal was to develop research and action agendas based on an in-depth understanding of the determinant role and interaction of stratifying forces embedded in educational and professional processes and outcomes. The symposium aimed to explore strategies for capacity building and broadening STEM participation. Accordingly, key tasks for participants included delineating and engaging the SoBP as a critical platform for transformative dialogue and action.

In-depth roundtable discussions among participants centered on four principal themes: frameworks, measures, education, and workforce. Summative presentations were given at the end of the first day, with further discussion on the second day of pathways toward broadening participation in the STEM fields and workforce. In the end, there were four key takeaways — indeed challenges to the SoBP community of practice — regarding work that is needed to provide a contextualized and sound evidentiary basis for broadening the STEM participation and representation of women, minorities, and people with disabilities:

- Curated knowledge from various areas of study related to understanding and assessing underrepresentation in STEM fields.
- Curated data, metrics, and statistics from various areas of study related to understanding and assessing underrepresentation in STEM fields.
- Curated knowledge from various areas of study assessing educational attainment and effects, contextualizing educational access, opportunities, and outcomes, and identifying critical causes of underrepresentation in STEM fields.
- Curated knowledge from various areas of study for identifying workforce dimensions and dynamics, contextualizing occupational access, opportunities, and outcomes, and investigating recruitment, retention, and network characteristics that result in underrepresentation in the STEM workforce.

In addition, participants stated that any SoBP program should emphasize and foster scalable and sustainable solutions based on evidence. The need to communicate the value of a SoBP also was emphasized by participants, positing particularly the importance for the research to

have practical resonance. Moreover, participants urged researchers to embrace the challenge of the SoBP and to take the risk of developing disruptive paradigms that could support real and positive changes leading to the broadened participation and inclusion of women, minorities, and people with disabilities in STEM.

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Symposium on the Science of Broadening Participation

25-26 February 2016
Arlington, Virginia Arlington Hilton

Thursday, 25 February 2016 (Gallery 1 – Gallery 2, Mezzanine Level)

A.M.	7:30 – 8:30	**Registration and Continental Breakfast**
	8:30 – 9:00	**Welcome and Defining the Scope**
	9:00 – 10:00	**Plenary: Why is there a need for a *scientific* approach to broadening participation in the STEM fields and workforce?** **Jeryl Mumpower**, Texas A&M University **Heather Metcalf**, Director of Research and Analysis, Association for Women in Science **Hannah Valantine**, Chief Officer for Scientific Workforce Diversity, National Institutes of Health
	10:00 – 10:30	Break and assemble into groups for roundtable discussions
	10:30 – noon	**Concurrent Roundtable Discussions I** **Thematic Charges** **Frameworks: Amanda Bayer**, Swarthmore College **Measures: Donna Ginther**, University of Kansas **Roundtables** **(a) What are the frameworks that *should* inform assessment of underrepresentation relative to employment, education, and policy processes and outcomes?** **(b) What are the evaluative measures that should be used to identify underrepresentation in STEM fields? Is there a need for new data and new metrics?**
P.M.	Noon – 1:30	**Lunch**
	1:30 – 2:30	**What Works: Dimensions of Accessibility and Participation** **Moderator:** **Paul Baker**, Georgia Institute of Technology **Panelists:** **Mary Ann Leung**, Sustainable Horizons Institute **Tamitha C. Tidwell**, University of Washington **Emorcia Hill**, Harvard University
	2:30 – 3:00	**Break** and assemble into groups for roundtable discussions
	3:00 – 4:30	**Concurrent Thematic Roundtable Discussions II** **Thematic Charges** **Education: Gertrude Fraser,** University of Virginia **Workforce: Roli Varma**, University of New Mexico **Roundtables** **(c) To what extent is education both means and ends in STEM participation?** **(d) How has the U.S. workforce been affected by underrepresentation of minorities, women, and people with disabilities?**
	4:30 – 5:30	**Roundtable Group Reports and Open Discussion** **Erik Kuiler**, George Mason University **Samuel Myers, Jr.**, University of Minnesota **Ana Ferreras**, National Academy of Sciences **Willie Pearson, Jr.**, Georgia Institute of Technology
	5:30 – 7:00	**Reception and Networking**

Supported by the National Science Foundation, Science of Science and Innovation Policy Program:
Kaye Husbands Fealing, Georgia Institute of Technology, Award #1551904
Connie L. McNeely, George Mason University, Award #1551880

Friday, 26 February 2016 (Gallery 1 – Gallery 2, Mezzanine Level)

A.M.	7:30 – 8:30	**Registration and Continental Breakfast**
	8:30 – 9:00	**Welcome and Opening Remarks**
	9:00 – 10:30	**Panel Discussion: Why is there a need for a *scientific* approach to broadening participation in the STEM fields and workforce?** **Moderator:** **Jong-on Hahm**, George Washington University **Panelists:** **Ingrid Padilla**, University of Puerto Rico, Mayagüez **Donna Ginther**, University of Kansas **Cecilia Conrad**, MacArthur Foundation
	10:30 – 11:00	**Break**
	11:00 – 12:00	**What are clear evidence-based pathways to broadening participation in STEM fields within and across academia, industry, and government?** **Bill Valdez**, Consultants International Group, Inc. **Krishna Athreya**, AAAS-COOS & Center for Biorenewable Chemicals, Iowa State University
P.M.	12:00 – 12:30	**Action Agenda and Closing Remarks** **Maryann Feldman**, National Science Foundation **Connie L. McNeely,** George Mason University **Kaye Husbands Fealing**, Georgia Institute of Technology

Roundtable Moderators

Frameworks
Jong-on Hahm, George Washington University
Erik Kuiler, George Mason University
Daniel Styer, Sacramento City College
Patricia White, National Science Foundation

Measures
Robbin Chapman, Wellesley College
Lisa Frehill, Energetics Technology Center
Samuel Myers, Jr., University of Minnesota
Yu Tao, Stevens Institute of Technology

Education
Ana Ferreras, National Academy of Sciences
Marilyn Mobley, Case Western Reserve University
Kimberly Saunders, University of Delaware
Cheryl Wilga, University of Alaska, Anchorage

Workforce
Mary Ann Leung, Sustainable Horizons Institute
Ernest McDuffie, The Global McDuffie Group
Willie Pearson, Jr., Georgia Institute of Technology
Ester Sztein, National Academy of Sciences

Roundtable Note Takers
Brian Donahue, George Mason University
Kevin Donahue, University of Mary Washington
Patricia Donahue, George Mason University
H. Aaron Finney, George Mason University
Joel Hicks, George Mason University
Lutheria Peters, George Mason University
Alfred Sarkissian, George Mason University
Thomas J. Scavone, George Mason University
Katie Seely-Gant, Energetics Technology Center

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Gia Cromer, George Mason University
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Supported by the National Science Foundation, Science of Science and Innovation Policy Program:
Kaye Husbands Fealing, Georgia Institute of Technology, Award #1551904
Connie L. McNeely, George Mason University, Award #1551880

Symposium
on the
Science of Broadening Participation

25-26 February 2016
Arlington, Virginia

Initial Participant List

Krishna Athreya, AAAS-COOS, Iowa State University

Paul M.A. Baker, Georgia Institute of Technology

Wenda Bauchspies, National Science Foundation

Amanda Bayer, Swarthmore College, Federal Reserve Board

Charles Betsy, Howard University

Frances Carter-Johnson, National Science Foundation

Robbin Chapman, Wellesley College

Elfreda Chatman-Walker, Case Western Reserve University

Cecilia Conrad, MacArthur Foundation

Fay Lomax Cook, National Science Foundation

Lisa Cook, Michigan State University

Gia Cromer, George Mason University

Jessie DeAro, National Science Foundation

Catherine Didion, National Academy of Engineering

Brian Donahue, George Mason University

Cato Laurencin, University of Connecticut

Mark Lawson, University of California, San Diego

Mark Leddy, National Science Foundation

Cheryl Leggon, Georgia Institute of Technology

Mary Ann Leung, Sustainable Horizons Institute

Ernest Marquez, SACNAS

Ernest McDuffie, The Global McDuffie Group

Connie L. McNeely, George Mason University

Jeffrey Mervis, *Science Magazine*, American Association for the Advancement of Science

Heather Metcalf, Association for Women in Science

Marylin Sanders Mobley, Case Western Reserve University

Andrea Y. Morris, Virginia Polytechnic Institute and State University

Jeryl Mumpower, Texas A&M University

Samuel L. Myers Jr., University of Minnesota

Brad Newsome, National Institutes of Health

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Ana Ferreras, National Academies of Sciences, Engineering, and Medicine

H. Aaron Finney, George Mason University

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Lisa Frehill, Energetics Technology Center

Kenneth Gibbs, National Institute of General Medical Sciences

Donna Ginther, University of Kansas

Stacie Gregory, American Society for Engineering Education

Jong-on Hahm, George Washington University

Evelynn Hammonds, Harvard University

David Hart, George Mason University

Joel Hicks, George Mason University

Sharon Hicks-Bartlett, University of Chicago

Emorcia Hill, Harvard University Medical School

Tasha Inniss, National Science Foundation

Sylvia James, National Science Foundation

Jolene Jessie, National Science Foundation

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