Improving Access to STEM:
Challenges and Commitments

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and

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Hunter Rawlings, President, Association of American Universities.

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Conference Schedule

9:00am: **Welcome / Framing**

- Russell Moore, Provost, Colorado University Boulder
- Danielle Carnival, Senior Policy Advisor, White House Office of Science and Technology Policy
- Hunter Rawlings, President, Association of American Universities
- Howard Gobstein, Executive Vice President, Research, Innovation, and STEM Education, Association of Public Land-grant Universities

9:30am: Plenary panel: **Innovation in STEM Teaching and Learning**

- Moderator: Jo Handelsman, Associate Director for Science, White House Office of Science and Technology Policy
- Susan Singer, Director, Division of Undergraduate Education, NSF
- Michael Marder, Professor and Executive Director UTeach Science Program, University of Texas at Austin
- Shirley Malcom, Head of Education and Human Resources Programs, AAAS
- Vincent Tinto, Distinguished Professor Emeritus, Syracuse University
- Charles Henderson, Professor, Western Michigan University

10:45am: **Thematic Working Sessions**

- Topic #1: STEM Introductory Course Redesign (active learning)
    - Susan Singer, Director, Division of Undergraduate Education, NSF
- Topic #2: Experiential learning to transform undergraduate education
    - Michael Marder, Professor and Executive Director UTeach Science Program, University of Texas at Austin
- Topic #3: Pathways: Access and Success in STEM Education
    - Shirley Malcom, Head of Education and Human Resources Programs, AAAS
- Topic #4: Strategies & Factors Promoting Persistence
    - Vincent Tinto, Distinguished Professor Emeritus, Syracuse University
- Topic #5: Institutional Change Strategies
    - Charles Henderson, Professor, Western Michigan University

12:45pm: **Keynote from Jo Handelsman**, Associate Director for Science, White House Office of Science and Technology Policy

1:15pm: Plenary Remarks: **Barriers, Opportunities, and Success**

- Daniel Porterfield, President, Franklin and Marshall College
- Rebecca Blank, Chancellor, University of Wisconsin-Madison

2:15pm: **Facilitated Working Session:** small group discussions

3:30pm: **Report-outs and next steps**

- Danielle Carinval (facilitator)

Improving Access to STEM:
Challenges and Commitments

Overview and Background

On January 16, 2014, the White House held an event to promote their College Opportunity Initiative, designed to improve access and quality of college education (White House, 2014). The President and First Lady called for a "sustained all-hands-on-deck effort" to increase college opportunities for low-income and traditionally disadvantaged students in the USA. As a result of that event, college and university leaders, foundations, non-profits and others made 100 new institutional commitments to help achieve this goal.

To sustain momentum towards institutions achieving these commitments, in fall of 2014, the White House Office of Science and Technology Policy (OSTP) held four events at which thought leaders met to discuss and make continued progress towards their commitments. The four meetings were held at four different universities, each a week apart. The first event was held at the University of Maryland, the second at the University of Colorado, Boulder, the third at Florida International University, and the fourth at California State University, Northridge. The purpose of these four events taken together was to continue to engage institutions of higher education, to support their individual efforts, to seed collective action, and to build momentum for a December 4th event, at which institutions will have opportunities to discuss and refine existing commitments.

Decades of research have resulted in a vast body of literature describing numerous innovative teaching approaches in STEM educational transformation. These approaches are known to improve student learning, but by and large they are not well adopted (Henderson, Beach, and Finkelstein, 2011). Accordingly, improving the adoption of such approaches was a primary focus of the *Engage to Excel* report that in many ways served as a precursor to this event (PCAST, 2012). Research shows that individual efforts towards reform in STEM are unlikely to succeed; instead, effective STEM transformation requires a systemic approach (Henderson, Beach, Finkelstein, 2011). The need for a collaborative, systems approach to addressing issues of access in STEM was a recurrent theme throughout the conference.

This conference report describes the outcomes of the second meeting, at the University of Colorado, Boulder. The broad goal of the meeting was to identify, evaluate, and scale innovative ways to improve STEM teaching and learning and to broaden STEM degree completion to more students. Concretely, the meeting focused on institutional commitments made by the institutions represented by nearly 100 participants who attended the meeting. This report focuses on the key opportunities and challenges that participants identified and outlines next steps for moving forward to address these challenges and opportunities. The event was segmented into major components, which frame the outcomes in this report: (1) the morning plenary and introductory framing, (2) morning breakout sessions focusing on access and quality in STEM education, (3) the

keynote address and plenary talks, and (4) community identified challenges and opportunities faced in meeting institutional commitments. The report closes with a suggestion for next steps and a list of references identified by participants.

STEM Transformation: A Collaborative Effort
Calls and Outcomes from Morning Sessions

The morning session consisted of four speakers – Russell Moore (VCAA at CU Boulder), Danielle Carnival (White House OSTP), Hunter Rawlings (President, AAU), and Howard Gobstein (Executive Vice President, APLU) – who emphasized the need a collaborative effort to transform STEM education. The discussion, summarized below, focused on three major issues: (1) the connection between access to STEM and college access broadly, (2) scaling of individual transformation efforts, and (3) the need for cultural change. In each of these categories, CU Boulder was praised for its efforts as a national leader and model of practice.

STEM transformation is difficult, but desperately needed, because issues of opportunity in STEM are related to issues of access more broadly. Mathematics and science courses are often the gatekeepers that prevent students from graduating, even in fields outside of STEM. For instance, about 60% of community college students start in remedial mathematics, and two thirds of these students never complete the remedial mathematics sequence (Cullinane & Treisman, 2010), making graduation impossible. As such, developmental mathematics is a contributing factor to great disparities in the earning of college degrees. Socioeconomic status also plays a huge role in degree completion; for the last several decades, 80% of students from the top economic quartile earned a 4-year degree (Lumina Foundation, 2013). In the bottom quartile students only 10% of students earned such degrees, and only 20% of students in the second lowest quartile earned such degrees. Not only is this an issue of equity and social justice, it severely limits the diversity of the workforce, which results in shortages of workers, and ultimately lower quality science.

Fortunately, there are a number of innovative programs that do improve learning in STEM. CU Boulder has launched a number of such efforts, including: PhET, the Learning Assistant Program, the Integrated Teaching & Learning Program and Laboratory, and the Idea Forge collaborative space for design. Examples of innovative programs can be found at many other institutions as well. At present, the problem is not the lack of innovative programs, but whether or not they can be scaled up and integrated into a systemic reform effort. To truly capitalize on the value of such programs, a community effort is required to share successes, failures, and lessons learning the process. These networks require multiple voices and multiple actors working together to address issues of access to STEM. Fortunately, efforts are underway to form and strengthen such networks. A few notable examples with which Colorado is affiliated are: the Colorado Education Initiative (STEM Roadmap), the APLU Mathematics Teacher Education Partnership (MTEP), the AAU STEM Education Initiative, and the BayView Alliance.

Ultimately, to achieve widespread STEM transformation, cultural change is required. The AAU's Undergraduate STEM Education Initiative is focused on precisely this goal. This initiative is focused on cultural change in STEM departments as a mechanism to improve

the use of evidence-based teaching. Funding from the National Science Foundation and Helmsley trust supports this effort. Recognizing the important of improving access in STEM, the AAU has provided strong national support to this effort. For transformation efforts to succeed and be sustained, they must focus on departments, not just individual faculty or courses. Locally, this department-focused approach is central to the change efforts. Efforts at CU Boulder, first through the Science Education Initiative and now the AAU effort, have demonstrated the potential for impact at the department level.

Key Themes and Challenges
Morning Breakout Sessions

The morning breakout sessions were organized around five key themes, each led by a leader in the field. The themes and their leaders were: introductory course redesign (Susan Singer), promoting early experiential learning experiences (Michael Marder), access and success (Shirley Malcolm), persistence (Vincent Tinto), and institutional change strategies (Charles Henderson). Each session consisted of participants collaboratively discussing the issues with the session leader.

Theme 1: Introductory Course Redesign

The Federal STEM Education 5-year strategic plan is organized around four objectives related to introductory STEM courses (NSTC, 2013):

1. **Evidence-based Practices:** Identify and broaden implementation of evidence-based instructional practices and innovations to improve undergraduate learning and retention in STEM and develop a national architecture to improve empirical understanding of how these changes relate to key student outcomes;
2. **Community Colleges:** Improve support of STEM education at 2-year colleges and create bridges between 2- and 4- year postsecondary institutions;
3. **Research Experiences:** Support and incentivize the development of university-industry partnerships, and partnerships with federally supported entities, to provide relevant and authentic STEM learning and research experiences for undergraduate students, particularly in their first two years; and
4. **Mathematics Success:** Address the problem of excessively high failure rates in introductory mathematics courses at the undergraduate level to open pathways to more advanced STEM courses.

Each of these objectives is based on the principle that systematic, sustainable efforts are required to transform STEM education. The need for broader implementation of evidence-based instructional practices is emphasized in key reports (PCAST, 2012, NRC, 2013), and soon the NRC will release a practitioner's guide for implementing these strategies. A number of efforts are underway to support dissemination of practices, including: tools to automate the grading of short answer responses (e.g., at MSU and Maine), promoting collective ownership of introductory STEM courses (at University of Illinois), and CIRTL's efforts to help future faculty use evidence-based practices. In addition

to supporting dissemination of strategies, developing metrics for their use is a strategic focus of the AAU's STEM Education Initiative and the AAAS's measures of teaching practices.

Participants in the session discussed two case studies of transformations at CU Boulder: Concept Assessments in biology, and introductory course reform in physics. Concept Assessments are multiple-choice questions in biology that are used to diagnose conceptual difficulties that students have. They are not used for the purpose of grading, but understanding how well students are meeting stated learning goals. The assessments help highlight that, even after instruction, students hold non-normative ideas in biology. In the physics department, Learning Assistants (LAs) have been included into the introductory physics course to implement physics tutorials (from McDermott U Washington), which has resulted in notable gains in student learning.

Community colleges are central to objectives (2) and (4). A notable program is the NSF's Community College Innovation Challenge, which provides opportunities for community college students themselves to come up with solutions to challenges that community colleges face. Teams of community college students have an opportunity to submit a plan, and the top ten teams will travel to Washington, D.C. to attend an entrepreneur workshop. The top team will receive funding to implement their plan.

Community colleges are also engaged in efforts to facilitate the transition from 2-year to 4-year programs. This involves dual credit programs, aligning the workforce requirements with teaching, and broadening participation. These efforts are desperately needed given the low completion rates of developmental mathematics courses (Cullinane & Treisman, 2010). One notable program that has worked to address this issue is the Statway program through Carnegie; the program has tripled student success in half the completion time (Van Campen, Sowers, Strother, 2013). Other notable efforts beyond community colleges are the national study of calculus programs led by David Bressoud and the Mathematics Association of America's launch of a new journal specifically focused on undergraduate mathematics, International Journal of Research in Undergraduate Mathematics Education.

There is a growing recognition of the value of early research experiences, but presently they are not widely available. NSF has funded several hundred grants to give course-based research opportunities. There is also a new hub, CureNET, which provides a centralized location for learning about such opportunities. These experiences were the focus of topic 2.

Topic 2: Promoting Early Experiential Learning

Having opportunities to engage in authentic science practices early in one's college career is shown to improve learning and retention. One notable example is UT Austin's Freshman Research Initiative (FRI; UT Austin, 2014). This initiative has provided opportunities for over 700 freshman to go into research laboratories. The FRI spans three semesters of integrated coursework and laboratory research, with students moving through the program in cohorts of 30. The program recruits 50% women and 50% students from underrepresented groups. As a result of the program, students have a 35%

higher graduation rate, with 30-35% improvement in retention for all FRI participants, and even greater 43-51% retention for Hispanic FRI students.

The promotion of early experiential learning opportunities is in contrast to a growing push for more "efficient" education. The rhetoric on efficiency focuses on increasing the size of classes and teaching with more technology. The problem with these approaches is that they don't focus on students as whole individuals, and they disproportionately weed out underserved populations. To address this, we need to redefine what is considered "efficient," and focus on meeting student needs through authentic experiences and community.

A parallel effort at Austin, the UTeach initiative provides another experiential learning approach to promote undergraduate engagement in STEM, particularly targeting the recruitment and preparation of future pre-college STEM teachers. From the UTeach Institute: (http://uteach-institute.org):

> The UTeach model calls for a unique collaborative partnership between colleges of science, liberal arts, and education in preparing teachers who have deep content knowledge in their science, technology, engineering, and mathematics (STEM) discipline, are proficient in core scientific and mathematical practices, and are able to apply appropriate STEM pedagogical strategies to promote student mastery of core concepts, principles, and practices in mathematics and science. The UTeach program is currently active at 40 universities in 19 states with a total enrollment of more than 6,700 students. 90% of UTeach Austin graduates enter the teaching profession. Five years later, about 80% are still in schools.

Topic 3: Access and Success

The AAAS is focused on improving diversity. A guiding principle is that "if something doesn't work for majority of population, it doesn't work." Considering that women, underrepresented minorities, disabled students, and first-generation college students make up the majority of the population, STEM education is not working for them. There are six major issues around diversity that AAAS focuses on:

1. **Alignment between K-12 and Higher Education**. Teachers tend to teach how they were taught, and aren't being adequately prepared to teach with innovative pedagogies. Issues of testing and accountability further restrict teachers, which makes it hard for them to enact the pedagogies that are known to be helpful for students and that are valued in higher education.
2. **Navigating College.** College is a complex institution, especially for first-generation students. To address this issue, there are a number of efforts: S-STEM at Mount Holyoke College tends directly to this issue by providing navigational support; SACNAS allows for the blending of cultural, science, and service identities; and graduate student mentoring programs provide students with role models. These programs are all valuable, but the issue is how to scale them.
3. **Nontraditional Pathways.** Students often transfer between institutions, especially from community college to university. To support them, this transition needs to be as seamless as possible.

4. **Support Structures.** An ongoing tension exists between changing the system vs. changing the student. To really support students meaningfully, systemic changes are required.
5. **Curriculum to support teaching.** Active learning is critical to support students, and lecture-based methods most negatively impact underrepresented students. To support change, faculty need resources and support.
6. **Monetary support and a supportive community.** Students need monetary support. About 60% of African American students work 20 hours per week, which is too much for a full time STEM major. One solution is to align work for money with work that trains and reinforces STEM identity.

Each of these six issues can be connected to equity broadly or STEM specifically.

Topic 4: Persistence

Persistence, a core component of retention, can be seen as a social-psychological manifestation of motivation. By creating appropriate institutional structures, the university can help students become members of the scientific community by internalizing norms and practices. There are three related components of persistence: self-efficacy, community, and identity.

"Perceived self-efficacy refers to one's beliefs in one's capabilities to organize and execute the courses of actions required to produce given attainments" (Bandura, 1997; pg. 3). When it comes to self-efficacy, perception is much more important than actual capacity; simply holding the belief that one is capable of doing something improves performance. Self-efficacy can be hindered, however, by things such as stereotype threat; when traditionally marginalized individuals are placed under circumstances that highlight this status, it reduces their performance. Fortunately there are a number of effective interventions for reducing stereotype threat. These range from micro-interventions (Yeager & Walton, 2011), to reaffirming research opportunities.

Membership in a supportive community that values you is also a key part of persistence. Such social support can often be developed through active, applied, experiential learning. Cohort models and living learning communities are two examples of effective programs that leverage the importance of community.

The final component of persistence is identity. If students identify as scientists, they are more likely to remain in STEM, but if they see STEM as disconnected from their lives, they are less likely to do so. Authentic research experiences, supportive mentors, and internships are all means of providing authentic experiences that support identity development.

Topic 5: Institutional Change Strategies

Although effective pedagogies exist, they are not well adopted. Most recent change initiatives involve working with groups of individuals. The goal of such groups is to create emergent, local change. The challenge is that there are relatively few guidelines on how to effectively structure such groups. The default model for change efforts is to assemble a

group of people, give them a problem, and give them a year to work on it. However, this process could be better streamlined with a better underlying theory. Complexity leadership theory is one such theory that may help do that work (Borrego & Henderson, 2014). The theory consists of three phases: (1) disruption, (2) encouraging novelty, and (3) interpreting emergent events.

For novelty to occur, it is important to *disrupt* existing patterns. When old ideas are disrupted, it creates a context in which news ideas can emerge. New ideas do not emerge automatically. To *encourage novelty,* individuals need to feel autonomy and need to be working towards a clear, simple message that they can come back to and align their efforts. Appropriate conditions and messaging can be facilitated through effective leadership. As novel ideas and events begin to emerge, leadership can help *interpret* these events in a way that supports change; the leaders amplify good ideas but still allow the process to be emergent, rather than trying to control it.

Complexity leadership theory can be applied to understand a well-known example of course transformation, the Science Education Initiative (http://www.colorado.edu/sei). The example focuses on the transformation of upper division electromagnetics. In the disruption phase, 13 instructors met 7 times to develop learning goals, thereby questioning the standard practices of the course. To encourage novelty, an assessment instrument was developed to understand how goals were being met. Finally, to interpret emergent events, post-doctoral researchers worked behind the scenes to synthesize ideas and report back to the larger group; this course-level reform led to broader program level goals, and helped develop shared language in the department.

Keynote Address: The White House Agenda
National Perspectives of Challenges

STEM education is a major focus for the White House's agenda on education. There is a projected shortage of 1 million STEM workers by 2022 (PCAST, 2012). Not only is this an issue of equity, but also of the economic competitiveness of USA in the world. STEM critical thinking skills are key for STEM careers, but they also benefit individuals working in any career, because an understanding of the nature of the scientific process is generally valuable. Ultimately, the White House aims to have an abundance of individuals trained in STEM and for these individuals to actually represent the demographics of the USA. The major issue to creating such a workforce isn't recruitment, but retention; more than 60% of interested students leave STEM. There are three major groups of such students:

1. Capable students who do not enjoy being in STEM due to poor pedagogy.
2. Students who do not do well with current teaching methods, but could succeed with better pedagogy.
3. Students who enter college unprepared.

Through appropriate efforts, it should be possible to retain students from each of these groups. Issues of attrition are particular profound for students of color. Not only do they enter STEM majors at a lower frequency than White students, they are lost at a higher frequency.

The White House goal is to reduce loss from 60% to 50%, which would be enough to cover at least 75% of the million workers projected to be need for 2022 (PCAST, 2012). Most of the jobs that are projected only require degrees at the BS and AS level; more PhDs are not needed.

The first two recommendations from the PCAST report have the potential to help address these issues, and were the focus of the keynote (PCAST, 2012).

1. Catalyze the widespread use of evidence-based teaching practices.
2. Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.

Evidence-Based Teaching Practices:

A student enrolled in traditional lecture courses is twice as likely to drop out of college as a student in courses that use active learning (Felder, Felder, & Dietz, 1998). Unfortunately, the majority of classes are still lecture-based, even though there are is an abundance of active learning techniques and their positive impact is well documented. The goal of the White House is not to promote a specific teaching method, but to have faculty adopt *any* method that will better engage students.

To get faculty to adopt active learning methods, additional training is required. Training efforts should focus both on current and future faculty. An important part of this support is training faculty with active learning pedagogies; right now, most faculty lack good models of teaching. Simultaneously, the field needs to develop metrics that institutions can use to gauge their progress towards excellence in STEM education. These efforts must move away from individual classrooms, and instead focus on systemic institutional change. Appropriately structured grant programs as well support from university leadership and the leadership of key organizations (e.g., AAU, APLU) are key .

Discovery-based Research Courses

Traditional discovery courses often feature cookie-cutter experiments to have students "rediscover" known results, rather than giving students a chance to engage in authentic inquiry and experience real science. As a result, they fail to inspire students to persist in STEM. Students who engage in research early in college are more likely to persist. They experience science and actually see what it is like. They also learn in a community, which is important. To improve the implementation of discovery-based labs, the White House has two recommendations (PCAST, 2012):

1. Expand the use of scientific research and engineering design courses in the first two years through NSF grant funding.
2. Expand opportunities for student research and design in faculty research laboratories by reducing restrictions on Federal research funds and redefining a Department of Education Program.

Both of these recommendations focus on getting students to have authentic STEM experiences as soon as possible.

Plenary Addresses: Institutional Commitments
Examples of Transformative Actions

Rebecca Blank (Chancellor, University of Wisconsin-Madison) and Dan Porterfield (President, Franklin & Marshall College) responded to the keynote address, highlighting the challenges in achieving the PCAST goals and also by providing examples of success. The speakers highlighted the unique challenges that different types of institutions face.

Large research universities face a number of challenges: unprepared students, faculty who don't know how to teach diverse students, and disconnects between diversity and equity groups and the university. For instance, diversity and equity groups are often not connected to STEM, so they don't know how to advise students appropriately.

Despite these challenges, there are a number of successful initiatives at the University of Wisconsin, Madison: the POSSE program, Middle School Science (matching mentors and students), Mad biology (1 week intensive exposure program), three STEM residential colleges, and CIRTL (training graduate students in evidence-based pedagogy). These programs represent models that are being used at other institutions, and that can be scaled across institutions.

At Franklin & Marshall college, faculty teach all of the courses and mentor labs. By the time students graduate, 80% have already had opportunities to conduct research. Because there are no graduate students, faculty work directly with undergraduates, which provides a unique opportunity. Although the liberal arts college does not reach students at a broad scale, it can have a holistic focus on every learner. Franklin and Marshall was the first liberal arts college to create a POSSE cohort, with 10 students per year receiving scholarships.

Community Engagement: Key Themes and Actions
Afternoon Breakout Sessions

The afternoon session consisted of 11 round table discussions. Participants introduced themselves and their institutional commitments. The participants then discussed the morning sessions and how the new information might push them forward on their commitments. Conversations focused on challenges, opportunities for innovation, and the people and ideas that could help move things forward. Through their discussions, participants identified a number of challenges and core areas of focus for future work. Synthesis and enumeration of the most common challenges and opportunities are elaborated below.

Common Vision

Most participants who were not a part of the university administration did not have a clear sense of their institution's commitments. This highlighted the need for better communication about to achieve cohesion across the university.

Participants also pointed out that issues of vision and leadership are often exacerbated by disruptive changes in vision. When there is a lot of turnover, it becomes difficult to achieve a coherent course of action. Participants wondered what could be done to help smooth transitions, recognizing that many participants were facing such disruptive changes.

Incentive & Institutional Structures

Considerable support is required to enact active learning in the classroom. However, participant perspective suggested that there is little incentive or support for faculty to pursue transformative teaching practices. Teaching ability is not emphasized in hiring procedures or in promotion and tenure decisions in a meaningful way. As a result, even faculty who wish to focus on teaching are discouraged and provided negative incentives for engaging in such pursuits.

Additionally, faculty members are often forced to teach large lecture courses in classrooms that act as barriers to student-centered teaching. Finally, even interested faculty may be lacking the time and support to enact such teaching strategies. The barriers that faculty face differ by institutions; at R1 institutions there is major pressure to publish; at smaller liberal arts or community colleges faculty may lacking sufficient support in other ways, such as increasing teaching loads.

Systematic Integration of Efforts

Most work on institutional change thus far has focused on efforts to improve pedagogy at a local level (e.g., in a single course). While there are notable examples of innovation, such efforts have generally not resulted in widespread cultural change and reform. Accordingly, there is a need to better focus efforts at a systems level. Participants identified four key areas of focus: (1) access to resources, (2) measures for course outcomes, (3) early intervention programs, and (4) the balance of academic freedom and academic responsibility.

Access to resources is a major impediment to transformative change. Many innovative programs were discussed at this workshop, and participants were unaware of many of them. Accordingly, participants questioned why it was necessary to hold such a meeting just to learn more about what is going on. Participants felt there was a huge need to make resources more accessible, both for teaching and professional development. A preliminary list of resources generated by participants is given in Appendix A. This body of this report also serves as a resource for innovative programs. The practitioner volume of the NAS/NRC DBER report may address some of this need.

Beyond resources for teaching, measures of teaching effectiveness are required. Traditional exams and student surveys are insufficient for capturing the richer types of practices that are demanded by change efforts. Developing appropriate measures is a difficult, time consuming process, and an area where discipline-based education research (DBER) can be of great support to the larger community. Many measures exist already, so the question is how to make them widely accessible and widely adopted.

Participants highlighted a number of early intervention programs (e.g., bridge from K12, freshman research initiatives, cohort models), which show a lot of promise for improving student retention. These experiences also provide a basis for better integrating student learning through the program, if they can be built on appropriately. There is value for better documenting what programs exist, how they work, and how to scale them up.

The final issue raised by participants was of academic freedom and responsibility. At present, faculty are largely considered to be independently responsible for what goes on in their classrooms. As they keynote highlighted, the goal is not to prescribe a set of methods for faculty, but given what is known about how people learn, it is important that faculty adopt at least some these practices known to be more effective. In this sense, faculty have an obligation to do what is known to be best with their students. Thus exists the tension between freedom and responsibility. As the need for change is system, it is important that the majority of faculty adopt such practices, to provide a coherent learning experience for students.

Sustainable Funding Models

The cost of higher education is on the rise, and this can be a major barrier, especially for students from underrepresented groups. This highlights the need for a sustainable funding model that works for all students. Funding cuts have only exacerbated this desperate need (e.g., the reduction of Pell grants by congress).

Building Community

Many participants voiced active support of this working conference and the need for opportunities to engage with each other on continued basis. Within institutions, individual faculty (and administrators) are often working in isolation or do not have access to the appropriate resources (e.g. need for access to pedagogical tools, and systemic approaches). Beyond institutions, individuals found the opportunity to engage with like-minded individuals a valuable step to reinforce their own activities, identify potential solutions to common challenges, and to build to a more sustained movement. Whether continuing with additional conferences or building other mediums engagement (possibly online), access to one another and other like-minded individuals committed to systemic and sustained educational transformation proves to be a valuable approach for addressing challenges outlined in STEM education and the College Opportunity Initiative.

Summary and Conclusions: Calls from the Community

This conference focused on improving access to STEM education. Given the low levels of retention, especially for traditionally underrepresented students, a focus on retention was considered as a primary mechanism for increasing diversity in STEM and meeting the challenge of graduating 1 million more STEM workers by 2022. To rise to this challenge, a concerted, collective effort is required. Rather than operating in silos, innovative programs must function in networks, allowing for best practices to shared and refined across the university community. Rather than focusing on individual course change

efforts, broader cultural change efforts are required that address university departments as a whole. Rather than being seen as an add-on, teaching excellence must be integrated meaningfully into the life of the university. Rather than coming as a mandate from above, university vision and leadership must be developed and integrated coherently at all levels of the university.

This conference represents another step towards achieving the community and cohesion required to address systemic problems in STEM education. This event will help lead up to the White House's December 4th meeting, in which institutions will have opportunities to update and revising existing commitments, and also to develop new commitments. This conference also provides a foundation for continued conversation around issues of access in STEM; the connections developed between thought leaders must be nurtured and sustained if we are to achieve the changes required to improve access to STEM in a meaningful way.

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White House (2014). Office of the Press secretary, FACT SHEET: The President and First Lady's Call to Action on College Opportunity, available at: http://www.whitehouse.gov/the-press-office/2014/01/16/fact-sheet-president-and-first-lady-s-call-action-college-opportunity (retrieved 11 Oct 2014).

And full list of commitments: http://www.whitehouse.gov/sites/default/files/docs/college_opportunity_commitments_1-16-2014_updated_040414.pdf

A write-up highlighting some of the STEM commitments is here: http://www.whitehouse.gov/blog/2014/01/17/white-house-college-opportunity-event-new-commitments-announced-help-low-income-stud

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Appendix A: Resources from the Community

Conference attendees were asked to share "key resources, articles, books, organizations, and programs" with their fellow participants. Here are their responses.

Resources

Academy of Inquiry Based Learning, http://www.inquirybasedlearning.org/

Ambrose, S., Bridges, M., DiPietro, M., Lovett,M., Norman, M., & Mayer, R. (2010). *How Learning Works: Seven Research-Based Principles for Smart Teaching*. Jossey-Bass.

American Society of Engineering Education – Publications, https://www.asee.org/papers-and-publications

BayView Alliance, http://bayviewalliance.org/

Bean, J. C. (2011). *Engaging ideas: The professor's guide to integrating writing, critical thinking, and active learning in the classroom*. John Wiley & Sons.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). How people learn.

Brown, P. C. (2014). *Make It Stick*. Harvard University Press.

Characteristics of Successful Programs in College Calculus, http://www.maa.org/programs/faculty-and-departments/curriculum-development-resources/characteristics-of-successful-programs-in-college-calculus

Chen, X. (2013). STEM Attrition: College Students' Paths Into and Out of STEM Fields (NCES 2014-001). National

Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

Coats, L.T., Xu, J., & Davidson, M. L. (2012). No Child Left Behind and Outreach to Families and Communities: The Perspectives of Exemplary African American Science Teachers. Research Papers in Education, DOI:10.1080/02671522.2012.689317

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Hauser, C., Bailey, C., Elgin, S. C. R., & Lopatto, D. (2009). The Genomics Education Partnership. *The FASEB Journal*.

Hill, C., Corbett, C., & St Rose, A. (2010). *Why So Few? Women in Science, Technology, Engineering, and Mathematics*. American Association of University Women. 1111 Sixteenth Street NW, Washington, DC 20036.

Hurtado, S., Eagan, M. K., Tran, M. C., Newman, C. B., Chang, M. J., & Velasco, P. (2011). "We do science here": Underrepresented students' interactions with faculty in different college contexts. *Journal of Social Issues*,*67*(3), 553-579.

Iowa STEM, http://www.iowastem.gov/.

Johri, A., & Olds, B. M. (Eds.). (2014). *Cambridge Handbook of Engineering Education Research*. Cambridge University Press.

Kuh, G. D., O'Donnell, K., & Reed, S. (2013). Ensuring quality and taking high-impact practices to scale. *Washington, DC: Association of American Colleges and Universities*.

Laursen, S. L., Hassi, M.-L., Kogan, M., & Weston, T. J. (2014). Benefits for Women and Men of Inquiry-Based Learning in College Mathematics: A Multi-Institution Study. *Journal for Research in Mathematics Education*, *45*(4), 406–418.

Learning Assistant Alliance, http://www.learningassistantalliance.org

Mann, C. R. (1912). *The teaching of physics for purposes of general education*. Macmillan.

Meyerhoff Scholars Program, http://meyerhoff.umbc.edu/

NAMEPA, http://www.namepa.org/

NASPA, http://www.naspa.org/

National Research Council. (2013). *Adapting to a Changing World--Challenges and Opportunities in Undergraduate Physics Education*. Washington, D.C.: National Academy of Science.

NSF I-CORP program, http://www.nsf.gov/news/special_reports/i-corps/

Partnership for Undergraduate Life Science Education (PULSE), http://www.pulsecommunity.org/

Physport (formerly, PER User's Guide), https://www.physport.org

President's Council of Advisors on Science and Technology. (2012). Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President. *Executive Office of the President*.

POSSE Program (UW Madison), http://posseprogram.wisc.edu/index.html

Project Kaleidoscope's Summer Leadership Institute, http://www.aacu.org/pkal/stemleadership/index.cfm

Pre-College Enrichment Opportunity Program for Learning Excellence (PEOPLE), http://www.peopleprogram.wisc.edu/index.html

Redish, E. F. (2003). *Teaching physics: with the physics suite*. Hoboken, NJ: John Wiley & Sons.

Singer, S. R., Nielsen, N. R., & Schweingruber, H. A. (Eds.). (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. National Academies Press.

Simbio Virtual Biology Labs, http://simbio.com/

Sousa, D. A. (2011). *How the brain learns*. Corwin Press.

Steele, C. (2010). Whistling Vivaldi: How stereotypes affect us and what we can do. New York, NY: W. W. Norton and Company, Inc.

University of Colorado and University of British Columbia Science Education Initiative, http://www.colorado.edu/sei/, and http://www.cwsei.ubc.ca/

Vision and Change in Undergraduate Biology, http://visionandchange.org/finalreport/

Women in Engineering Programs and Advocates Network (WEPAN), http://www.wepan.org/

Xu, J., Coats, L.T., & Davidson, M. L. (2012). Promoting students interest in science: The perspective of exemplary African American teachers. American Education Research Journal 49(1), 124-154.

Appendix B: Challenges Identified by the Community

Conference attendees were asked to describe "a challenge at their institution that they would like to address and would welcome resources" to address. Participants provided a variety of responses, organized around five major themes.

1. Improving Diversity and Equity. Participants highlighted issues of both recruiting and retaining women and underrepresented minority students in their STEM programs.

2. Increasing Enrollment. Given the push to produce more successful STEM graduates, institutions are faced with growing numbers of incoming students. This increase in students is coupled with little increase in resources. It is a challenge to provide high quality education to all of these students, rather than turning them away or using traditional lecture methods rather than active engagement.

3. Support for Educational Transformation. A large number of participants focused on the need for better support for educational transformation. At one level, this involves better resources and framework for instituting cultural change and working with faculty. At another level, it involves learning to better receive administrative support to make changes happen (e.g., by changing tenure and promotion guidelines).

4. Resources and Support for Faculty. The support required for faculty to implement active learning in their classrooms comes at many levels. From the administrative side, there is little incentive or support for faculty to pursue transformative teaching practices. Additionally, faculty are often forced to teach large lecture courses in classrooms that act as barriers to student-centered teaching. Finally, even interested faculty may be lacking the time and support to enact such teaching strategies.

5. Support for Discipline-Based Education Research (DBER). DBER is often perceived as lower status than "pure" science research, and as a result receives less funding. This impacts the amount of research funded, as well as the availability of tenure-track positions for DBER.