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A Historical and Policy Perspective on Broadening Participation in STEM: Insights from National Reports (1974-2016)

Teirra K Holloman Holloman, Virginia Tech Department of Engineering Education

Teirra Holloman is a doctoral student in engineering education at Virginia Polytechnic Institute and State University, where she serves as a graduate research assistant. Teirra received her BS in Industrial Engineering from Clemson University. Her research interests revolve around broadening participation in engineering.

Dr. Walter C. Lee, Virginia Tech

Dr. Walter Lee is an assistant professor in the Department of Engineering Education and the assistant director for research in the Center for the Enhancement of Engineering Diversity (CEED), both at Virginia Tech. His research interests include co-curricular support, student success and retention, and diversity. Lee received his Ph.D in engineering education from Virginia Tech, his M.S. in industrial & systems engineering from Virginia Tech, and his B.S. in industrial engineering from Clemson University.

Dr. Jeremi S London, Arizona State University, Polytechnic campus

Dr. Jeremi London is an Assistant Professor of Engineering at Arizona State University in the Polytechnic School. London is a mixed methods researcher with interests in research impact, cyberlearning, and instructional change in STEM Education. Prior to ASU, London worked at the National Science Foundation, GE Healthcare, and Anheuser-Busch. She earned B.S. and M.S. degrees in Industrial Engineering, and a Ph.D. in Engineering Education from Purdue University.

Mr. Atota Bedane Halkiyo, Arizona State University

Atota Halkiyo is a second-year master's student in Education Policy at Arizona State University. He received a bachelor's and master's degrees in English Language and Literature and ESL from Jimma University and Addis Ababa University respectively, in Ethiopia. Before moving to the U.S., Atota taught ESL courses at Mada Walabu University for over seven years, where he also served the university assuming various positions such as being Quality Assurance Director, Teachers Development Leader, Pedagogy Trainer as well as English Language Center Coordinator. Atota was also a principal investigator of the project entitled "Engendering Higher Education Curricula", where he, along with four project members, investigated gender issues in higher education and devised comprehensive interventions in the form of training for students, academic, support and administrative staff as well as by writing guidelines for the university. Atota is interested in working to ensure equity and quality in higher education, particularly for international and underrepresented populations.

Gilbert Jew, Arizona State University
Dr. Bevlee A. Watford, Virginia Tech

Watford is Professor of Engineering Education, Associate Dean for Academic Affairs, Director of the Center for the Enhancement of Engineering Diversity, and the 2017-18 President of ASEE.

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Abstract
Over the last 40 years, more than 25 national reports have been published focused on broadening participation in science, technology, engineering and mathematics (STEM). Although scholarly literature oftentimes serves as one source of information on how to move toward parity with national demographics, national reports—produced by organizations, such as the National Academy of Engineering (NAE) and the National Society of Black Engineers (NSBE), and committees, such as the Committee on Women in Science and Engineering (CWSE)—are an underutilized source of insights. This paper presents the results of a modified umbrella review of 29 national reports published during 1974–2016 related to broadening participation of underrepresented groups in STEM. The reports in this analysis included 134 unique recommendations, which were synthesized into five themes, broadly labeled: (1) Practices, (2) Policies, (3) Culture & Climate, (3) Information & Knowledge, and (4) Investments & Commitments. These recommendations have implications for various stakeholders interested in advancing the long-standing effort to broaden participation in STEM. Additionally, our findings provide a historical and policy perspective that is useful for informing future efforts.

Introduction
From as early as 1974, there have been national discussions on ways to broaden participation in science, technology, engineering, and mathematics (STEM) pathways, including both education and the workforce (Lichtenstein, Chen, Smith, & Maldonado, 2014). While trends surrounding compositional diversity have improved for some groups, less progress has been realized for others—and in some instances, percentages have declined (Yoder, 2015, 2016). For example, between the years 2000 and 2015, the percentage of engineering bachelor's degrees earned by Hispanics has increased from 5.8% to 10.7%, while the percentage for African Americans has declined from 5.6% to 4.0% (Gibbons, 2009; Yoder, 2016). If the goal is to achieve parity in representation that reflects national demographics, this lack of progress is problematic. For this reason, African Americans are the minority group that is of most interest in this study.

In pursuit of progress, many national and university-based efforts have focused on increasing the number of African American men and women in STEM, in general, and engineering and computer science, specifically. For example, universities with Minority Engineering Programs have an explicit focus on recruiting and retaining students that come from this segment of the population. In addition, local chapters associated with organizations such as *Black Girls Code*, *CODE2040*, *#YesWeCode*, and *Hack the Hood* specifically focus on improving diversity in computing. Moreover, there are several national organizations focused on diversifying engineering (e.g., National Action Council for Minorities in Engineering (NACME), National Association of Multicultural Engineering Program Advocates (NAMEPA), and National Society of Black Engineers (NSBE)).

There are also entities within federal funding agencies focused on investing in broad participation of underrepresented groups in engineering—namely the National Science Foundation's Broadening Participation in Engineering (BPE) Program and INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science) initiative. Furthermore, more than 25 national reports have been published over the last 40 years that focus on broadening participation of underrepresented racial and ethnic groups in STEM. These reports are read by stakeholders at all levels and includes insights relevant to a variety of stakeholders focused on this problem. Due to the lack of progress and historical continuity of this conversation, we argue that there is a need to pause and reflect on what is already known about this problem about the barriers to progress, highlight existing recommendations for addressing it the problem, and ultimately, create a national agenda for making progress toward parity.

Overview of Larger Project

This work is one part of a larger collaborative NSF-funded study (Award #1647327 and #1647281). The goals of the larger study are to: (1) critically evaluate the research-to-practice cycle as it relates to broadening participation in engineering and computer science (CS) education and the workforce; and (2) set a national agenda for broadening the participation of African Americans in engineering and CS that is informed by existing literature and subject matter experts. In conducting this study, our goal is to understand and disseminate insights about the historical context and national-level conversations surrounding issues of broadening participation in STEM. By doing so, we hope the findings of this work will provide readers with actionable recommendations they can pursue in light of previous calls to broaden participation.

Purpose & Guiding Research Question

The purpose of this study is to synthesize recommendations from the national reports on broadening participation in STEM using a quasi-umbrella review approach. The research question guiding this study is: How can *recommendations from national reports focused on broadening participation in STEM published during the last four decades be categorized?* In reviewing the national reports, our desire was to advance understanding of what recommendations have been made since the conversation began in the 1970s. We also wanted to know when these recommendations were made and who had been called to action. We argue that understanding the who, what, and when of the recommendations is essential to developing a national strategy for moving forward in a way that does not duplicate previous efforts, and ultimately leads to the type of impact we long to realize. The next section describes the methods associated with results of this study.

Methodology: Quasi-Umbrella Review

An umbrella review is a mechanism for aggregating findings from pre-existing reviews (Grant & Booth, 2009). Created as a means to fill a need identified by the Cochrane Collaboration, the methodology enabled researchers to compile evidence from multiple Cochrane reviews into one accessible and usable document (as cited in Grant & Booth, 2009, p. 102). The principle objective of the methodology is to focus on a broad condition or problem and the interventions developed to address it (Grant & Booth, 2009). For example, researchers have published

reviews focused on public health interventions for asthma and psychosocial interventions for autism (Labre, Herman, Dumitru, Valenzuela, & Cechman, 2012; Seida et al., 2009).
A perceived strength of the umbrella review methodology is the ability to provide an overview of potential solutions to an issue without the loss of detail and specificity (Grant & Booth, 2009). Because our objective was to provide a holistic overview of recommendations that have been made over the last 40 years regarding broadening participation in STEM, we deemed the methodological process of an umbrella review advantageous (Aromataris et al., 2015). For this investigation, we reviewed and compiled recommendations from a collective of national reports written over the last 42 years. In this context, a national report is a document developed to provide a broad perspective of efforts that have been or should be made towards broadening participation in STEM. Because this work analyzed national reports as opposed to other systematic reviews, we have deemed this work a *quasi-umbrella* review.

In conducting the review, we completed the following steps. To begin, we identified and located national reports on broadening participation in STEM. Next, we sorted and summarized these documents, comparing each against inclusion criteria developed by the research team. We also assessed the quality of each documents. Following the verification of the accepted reports, we analyzed the recommendations to identify significant patterns across stakeholders and time. These steps are further discussed in the section below.

Search Strategy

As stated earlier, this quasi-umbrella review is a part of a larger study focused on broadening the participation of African Americans in engineering and computer science. Because the conversation around broadening participation has not historically been intersectional, we searched for reports where either race or gender were the primary focus. To identify potential data sources, we went to the National Academies Press (NAP) and did a broad search for "broadening participation" in STEM. The NAP is the publishing office for reports by the National Academies of Science, Engineering, and Medicine under a charter granted by the Congress of the United States (National Academies of Science, 2017). We also searched using phrases such as "women in STEM," "minorities in STEM", "women and minorities in STEM", as well as variations of these searches with "science technology engineering and math" instead of "STEM." We then went to the National Society of Black Engineers (NSBE) website and searched their database since the core of their mission aligns with the aim of the larger study (i.e., "to increase the number of culturally responsible Black Engineers" (National Society of Black Engineers, 2017)). Lastly, once an initial collection of reports was identified, we searched for national reports that were referenced in already collected national reports. Because the way in which we refer to STEM has changed over the years, reports were considered if they referred to any part of STEM—science, technology, engineering, or math. Documents were not excluded if they referred to STEM by another acronym, such as STE, or simply focused on engineering. This search strategy resulted in the identification of 45 reports.

Inclusion Criteria and Quality Assessment

Once we identified a corpus of reports, we transferred them to Mendeley, a reference management software, and sorted them based on perceived topic. Next, three members of the research team reviewed each document to identify the document's title, year, topic/research

questions/purpose of the report, context and source of information, key findings, recommendations, and anything else deemed important to note. This resulted in the creation of a master document that included a summary of each national report.

Next, the lead author reviewed each summary to determine if the focus of the report was adequately aligned to broadening the participation of African American men and women, and that the document was focused at a national level and not on a specific localized program or project. This resulted in the removal of 16 documents, leaving 29 reports to be analyzed. The remaining 29 reports were labeled with a number from R1-R29, as seen in the Appendix A. Documents are listed in no particular order, other than the order in which it appeared in the master document of report summaries. Of the 29 documents, 13 were focused on gender, 13 were focused on race, and 3 were intersectional and focused on both race and gender. Of the intersectional reports, one reported on African American girls, another reported on women of color, and the last reported on minority males.

Data Analysis

Following the selection of relevant reports, the research team began to analyze the findings from the 29 document summaries. In alignment with our stated purpose, each document summary (and accompanying document when necessary) was reviewed to capture the specific recommendations found in each national report. We also documented the stakeholder mentioned, the report it came from, and the decade during which the document was published using an Excel worksheet. The codebook can be found in Table 1. The list of examples for *Stakeholders* and *Decades* are exhaustive. The list of examples for *Recommendations* only presents a few examples because this process resulted in a master list of 139 recommendations. When a recommendation was duplicated, it was only noted once. For example, the need to "collect data on recruitment and retention" was revealed in a total of 3 different reports and called upon various stakeholders, as seen in Appendix B, Table B5.

Next, the list of recommendations was printed and clustered to identify emergent themes. The first round of coding was done by one researcher. Two researchers then reviewed the preliminary codes to identify larger themes and reach agreement on the sorting and clustering. Next, the themes for the recommendations were applied to the Excel sheet to search for any relationships that may exist between themes, stakeholders, and/or decades.

Table 1: Codebook with descriptions and examples of codes.

Codebook		
Code	Description	Examples
Stakeholder	Those called to action throughout the noted recommendations.	1. University Leaders – Trustees, Presidents, Provosts, Deans 2. Department Chairs & Faculty 3. Researchers 4. Societies – Scientific, Honorary 5. Journals 6. Federal Agencies, Federal Funding Agencies/Foundations 7. Policymakers 8. Governors & Congress 9. Industry

		10. K-12 – Schools, Teachers, Administrators, Districts 11. Parents 12. American Citizens 13. Media 14. Other – stakeholder not specified
Recommendation	Actions suggested to broaden participation in in STEM.	"Help girls recognize their career-relevant skills." "Improve access to all postsecondary education" "Changing the context of test-taking to eliminate stereotype threat."
Decade	Decade in which recommendations were made to stakeholders.	1. 1970 2. 1980 3. 1990 4. 2000 5. 2010

Results & Discussion

Following all coding, sorting, and clustering, we identified five themes: (1) Practices, (2) Policies, (3) Culture & Climate, (4) Information & Knowledge, and (5) Investments & Commitments. This remainder of this section includes insights about the themes that emerged and trends in recommendations over time.

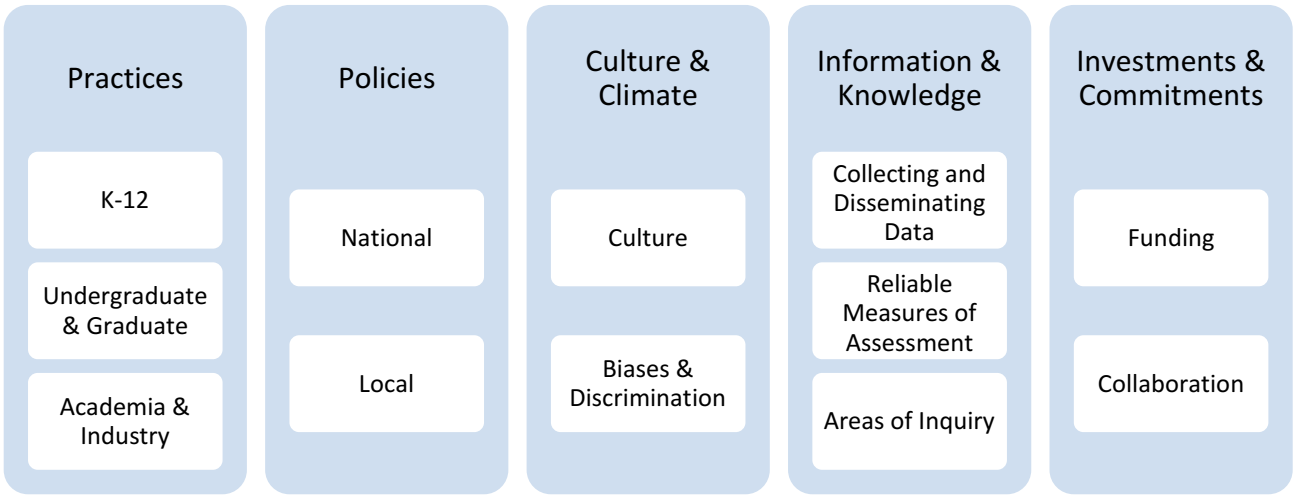

Figure 1: Recommendation categories from national reports on broadening participation

As illustrated in Figure 1, each theme consisted of 2-3 categories that further describe the nature of the recommendations identified throughout the 29 national reports (see Appendix A). In short, the Practice theme focuses on recommendations about actions that are aimed at improving the environment, process, and procedure for underrepresented people (i.e., students and professionals). The Policies theme is focused on recommendations that influence local and national strategies, procedures and protocols that impact the education and treatment of underrepresented groups. The Culture and Climate theme includes recommendations associated with improving the organizational culture and mitigating biases and discrimination found throughout organizations associated with STEM. The Information and Knowledge theme focuses on the acquisition, use, and understanding of facts associated with broadening participation in STEM. Lastly, the Investments and Commitments theme includes

recommendations about resources and partnerships that are necessary for broadening participation in STEM. These recommendations are calls to the 14 stakeholders previously identified (see Table 1). Each category and associated stakeholders are discussed in the following sections. Tables containing the full lists of recommendations can be found in Appendix B, and will be specified as "R#" (e.g., R17) hereafter for ease of reference.

Theme: Practice

Recommendations made with regard to what happens in practice are aimed at improving the environment, process, and procedure for underrepresented people at three specific levels: students (K-12), students (undergraduate and graduate), and professionals (academia and industry). Review of the recommendations found a consistency in the number of national reports on practice during 2000's and 2010's decades for each respective level. K-12 specifically saw a spike in reports produced during this timeframe going from five reports produced in the 31 years between the 1976 and 2007, to 7 reports produced in the 2010's alone.

Students - K-12

At the K-12 level, R23, R27, and R28 called for an overall improvement in the math, science and engineering education provided to students in K-12; while other reports, such as R7 and R17, address the need for offering informal hands-on learning and academic support like tutoring during school, after school, and over the summer. Just as recommendations varied across levels, the stakeholders named varied across levels as well. Recommendations made for improving the K-12 environments were directed at the following stakeholders: K-12, parents, American citizens, the media, and other.

Students - Undergraduate & Graduates

At the undergraduate and graduate level, R29 recommends that stakeholders properly train personnel involved in minority engineering programs and use test score results as more of a guidance tool and less as acceptance/rejection criteria for minority students. Recommendations made for improvements at the undergraduate and graduate level were directed at university leaders, department chairs and faculty, and a few "other" stakeholders.

Professionals – Academia & Industry

Examples of recommendations at the professional level include actively recruiting women and underrepresented minorities into STEM majors and higher education faculty positions, as recommended by R8, R17, R28, and R29. These recommendations were directed at department chairs & faculty, societies, federal agencies, and industry.

Theme: Policies

Policy recommendations target improvements to be made to strategies, procedures and protocols that effect the education and treatment of historically underrepresented groups in STEM at the national and local level. In contrast to practice related recommendations, there is *inconsistency* in the number of national reports regarding policy during the 2000's and 2010's. When looking across levels, reports were more frequent at the local level and less frequent at the national level during 2000's decade; the opposite was true during the 2010's decade.

National

At a national level, R27 recommended improved access to all postsecondary education; and R16 recommended the design of new policy levers that help STEM become more inviting for underrepresented groups. Stakeholders being called to action included all American citizens, federal agencies, policymakers, and others.

Local

An example of a local policy recommendation is to include enforcement of Title IX in STEM, recommended from R8, and to clearly relay performance standards and expectations, recommended from R8, R17, and R26. Because of this breadth, stakeholders included 9 of the 14 categories previously identified: university leaders, department chairs & faculty, societies, federal agencies, policymakers, governors & congress, industry, K-12, and other.

Theme: Culture & Climate

Culture & Climate recommendations are aimed at improving organizational culture and mitigating biases and discrimination found throughout these organizations along the STEM pathway. Publication of national reports addressing culture and climate reflected more frequency during the 2000's and even increased frequency in 2010's, similar to consistency found with regard to practice.

Culture

Culture refers to the shared ideas, attitudes, underlying assumptions, and practices among a group of people. An example of a recommendation in this category was pushing to make the U.S. the most attractive setting to study and perform research, as found in R23. To get there, authors recommend sending an inclusive message about who makes a good science or engineering student, as seen in R8. In addition, R2 recommends that stakeholders think strategically about the message leadership sends out regarding women in science. Several reports, R1, R6, R7, R13, R17, and R24 outright call for leadership and new policies that will change the culture and structure of these institutions in order to help increase the number of underrepresented minorities in STEM. This need to change the culture of STEM called various stakeholders to action including university leaders, department chairs & faculty, societies, federal agencies, policymakers, industry, American citizens, media, and other.

Biases & Discrimination

Throughout the literature, underrepresented groups often bring to light a phenomenon called "chilly climates" (as seen in Lichtenstein, Chen, Smith, & Maldonado, 2014, p. 321). This phenomenon manifests in multiple ways, including sexual harassment, a lack of opportunities to advance, and wage disparities. Unsurprisingly, a plethora of recommendations target some of these issues, hoping to mitigate this kind of environment and put an end to discrimination. To begin, several reports (R3, R7, R17, and R24) call for training individuals to recognize their biases they may not be aware exist. While acknowledging these biases, R1, R16, and R18, call for immediate implementation of programs and strategies shown to minimize the effect of biases in recruiting, hiring, promotion, and tenure. Again, these recommendations were

presented for a range of stakeholders: university leaders, department chairs & faculty, societies, journals, governors & congress, industry, K-12, American citizens, and other.

Theme: Information & Knowledge

Information and knowledge recommendations relate to the acquiring of information, use of information, our level of understanding the facts surrounding broadening participation in STEM. Consistency in publications from the 2000's to 2010's was also seen with regards to information and knowledge across all 3 levels, moving from two to three publications each to four to five publications each.

Collecting and Disseminating Data

Multiple reports collected directly called for better collection of data on women, underrepresented minorities, and minority engineering programs in STEM, R2, R15, R16, R17, and R29. Others (R2, R23, R25) called for data collection on recruitment and retention. There were also recommendations wanting to ensure that these data were disseminated to people in academia, government, industry, and professional societies. Stakeholders in these recommendations were a bit more specific compared to those in the Culture & Climate categories, with researchers, societies, federal agencies, and policymakers being the select few mentioned.

Reliable Measures of Assessment

Although, reliable measures of assessment compose one of the smallest categories, containing only 5 unique recommendations, the number of reports that repeated the same recommendations marked this category worthy of its separation from the mix of other recommendation categories. For example, 9 reports (R10, R12, R15, R17, R18, R20, R21, R24, and R25) recommend that stakeholders need to identify and report effective educational programs, curricula, schools, and best practices for recruitment and retention of underrepresented groups in STEM. R13, R15, R18, and R19 recommend stakeholders monitor undergraduate student progress to assess where we lose women and minorities along the STEM pathway. These recommendations and three others all lead to better understanding of how far we have come in broadening participation and see how far there is to go. In this category, university leaders, department chairs & faculty, researchers, American citizens, and other were called to action.

Areas of Inquiry

Throughout the 29 reports reviewed, many were filled with recommendations for areas to further investigate and gather information on through research. For example, R11, R12, R14, R25, and R28, all request further inquiry around areas affecting women and underrepresented minorities in science and engineering. Although very vague, further exploration into these documents can provide more context and in-depth understandings of their specific meanings. On the other hand, R2, R13, R15, and R25 recommend the search, development, evaluation, revision, and dissemination of models around career development, mentoring, recruiting, and advancement of underrepresented groups in STEM. R16 specifically called to enhance research capacity and research opportunities at Tribal colleges to advance Native Americans in STEM.

These recommendations called university leaders, department chairs & faculty, researchers, societies, federal agencies and other to be a part of the investigation to find out more.

Theme: Investments & Commitments

Investments and commitments is a category of recommendations related to resource allocation and necessary collaborative partnerships to aid broadening participation in STEM. Recommendations impacting investments and commitments also saw an influx and consistency across the 2000's and 2010's as seen in other categories previously mentioned.

Funding

Multiple reports talked of a need to distribute funds in places such as financial aid, program support, and research in order to help broaden participation. For example, R17, R18, R26, R27, and R28 all recommend providing financial support for financial aid programs and intervention programs designed to increase the number of underrepresented groups who complete training in math, science, and engineering. R13 and R25 recommend funding for longitudinal evaluations of selected programs. On a larger scale R17 recommends ensuring adequate funding levels for each school district in every state. Stakeholders include university leaders, department chairs and faculty, federal agencies, governors and congress, industry, and other.

Collaboration

One of the largest categories is the collection of recommendations for collaboration amongst various stakeholders to provide a joint effort for increasing the number of underrepresented groups in STEM. Collaborations range from coordinating transfer programs from two-year to four-year institutions, R17 and R24; to parents motivating their employers to donate equipment, money, and personnel to their children's school, R17. Reports such as R9, R17, R24, and R29 all call for strengthened university-industry partnerships; while R24 and R29 recommend that stakeholders should leverage professional societies and organizations. More broadly, R22 recommends STEM diversity be a global effort of sharing and communicating information in an ongoing, global learning community. Unsurprisingly, stakeholders also range in this category as they include university leaders, department chairs & faculty, societies, federal agencies, governors & congress, industry, K-12, parents, American citizens, and other.

Miscellaneous Recommendations

It is also important to note that there were a few recommendations within the 29 national reports that performed as outliers and did not fit well within the themes and categories discussed above. These recommendations included recognizing psychology as a STEM discipline (R15) and making laboratories accessible and adapted to persons with disabilities. Recommendations like these were outside the scope of our focus during this investigation.

Themes Over Time

Figure 2 depicts the number of recommendations that were included in the national reports over time, organized by them.

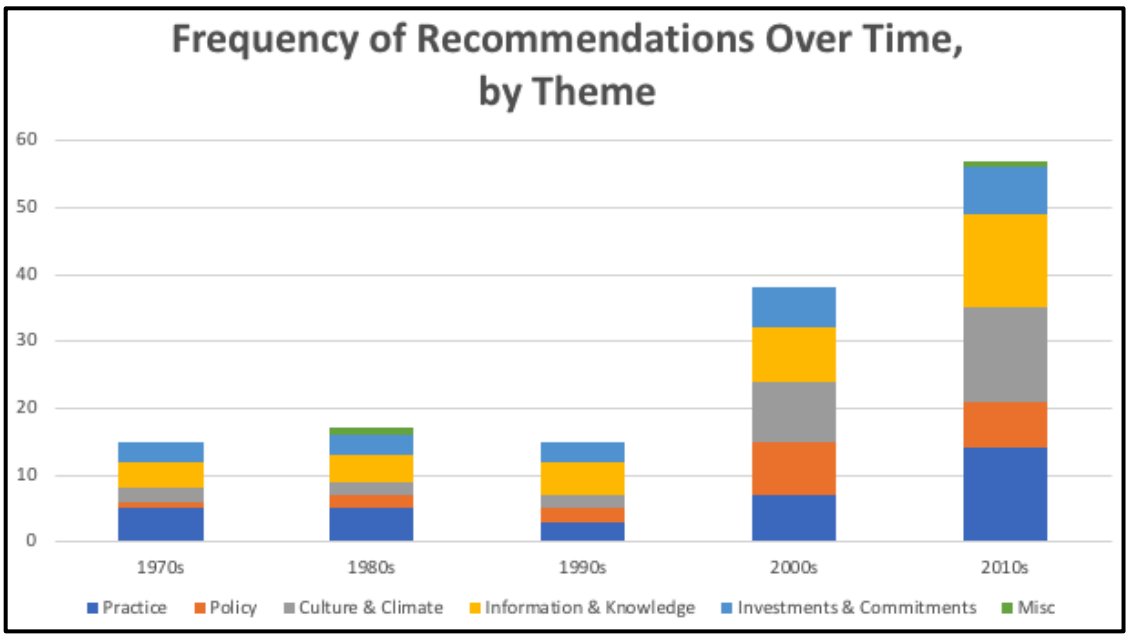

Figure 2. Trends in Recommendations by Theme

What emerges immediately from this figure is the sharp increase in the number of recommendations included in the national reports during the last two decades. The trend also shows that each decade includes recommendations associated with each theme, except for the two recommendations that fell into the "Miscellaneous" theme. What may not be as obvious from the graph is the two themes with the largest number of recommendations—namely "Information and Knowledge" and "Practice." When considering our results collectively, we found that there is a consistency in the "Practice" recommendations for both students (undergraduates and graduates) and professionals (in academia and industry) starting in the 2000s. In contrast, the trend shows a lack of consistency in policy recommendations. This theme along with the "Investments and Commitments" theme are among the smallest. Lastly, undergraduate education has been a consistent topic of interest, while the emphasis on K-12 education have grown over time. Less attention has been given to other sections of the education-to-workforce pathway (e.g., graduate education).

Implications & Conclusion

The research question that guiding this study was: *How can recommendations from national reports focused on broadening participation in STEM published during the last four decades be categorized?* The analysis and synthesis of the umbrella review led to nearly 140 recommendations that were categorized into five main themes. The themes range from a focus on practical things that individuals can do to policies and investments that influences the activities of larger groups of people.

The variety of themes and stakeholders suggest a few notable findings. One, issues associated with broadening participation of underrepresented groups in STEM result from a variety of underlying problems and, as a result, call for a multi-faceted approach to addressing this challenge. Two, the analysis across the sectors (e.g., university leadership, faculty, researchers,

scientific societies, policy-makers, funding agencies, industry, parents and all-American citizen) indicates generally similar distribution of responsibility in almost all thematic areas (practice and policy, culture and climate, information and knowledge as well as investment and commitments.) This implies that the issue of broadening participation is a challenge that requires the efforts, expertise, and influence of a wide range of stakeholders if we desire to be successful at achieving parity with national demographics someday. Given the complex, dynamic and multifaceted nature of the issue, we found that the comparable distribution of almost all of the themes across all stakeholders and sectors to be encouraging.

The trends over time reveal an increase the number of recommendations over the last two decades, though the type of recommendations has remained consistent over the years. Moreover, the increasing emphasis on K-12 STEM education is worth mentioning again. Although it is difficult to present a causal explanation, this increase in attention on this issue (as manifested by the increased number of the reports) could be associated with the increase in the number of the major U.S. educational laws/policies in the same decades [No Child Left Behind Act, (2002), America COMPETES Act, (2007), and Every Student Succeeds Act, (2015)].

An important detail to note about the contents of national reports was the lack of intersectional analysis found in the literature regarding race and gender. In particular, we noted that when the authors of the national reports were talking about women and recommending policies for women, they were seemingly doing so with white women in mind. While, localized reports and studies on Black women may be produced, the lack at the national level that focus on intersecting identities present an area for future work to address.

Overall, this study aimed to synthesize and categorize recommendations from 29 national reports produced during the last 40 years. In doing so, we found that there is a range in the types of recommendations found in these reports—from practical changes in classrooms, to policy changes, to large changes in organizational cultures. While we found no particular patterns as it relates to which types of recommendations have been made over time, it should be noted that as of 2010, reports have been generated at an increasing rate. We also note a wide range of stakeholders called to action in these recommendations, emphasizing that there is a clear role for everyone to play. Due to the persistence nature and complexity of this challenge, we recommend sustained attention to and equal ownership of addressing the associated issues by both local and national level policies and efforts. This work contributes to a larger study and provides a concise foundation for future efforts to move forward in areas where previous calls have been repeatedly made, and yet to be addressed.

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Appendix A: List of national reports reviewed.

ID#	Title	Citation
R1	Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering	(Committee on Maximizing the Potential of Women in Academic Science and Engineering, 2007)
R2	Achieving XXcellence in Science: Role of Professional Societies in Advancing Women in Science: Proceedings of a Workshop	(National Research Council, 2002)
R3	Biological, Social, and Organizational Components of Success for Women in Academic Science and Engineering: Workshop Report	(National Research Council, 2006a)
R4	Blueprint for the Future: Framing the Issues of Women in Science in a Global Context: Summary of a Workshop	(National Research Council, 2012)
R5	Solving the Equation: The Variables for Women's Success in Engineering and Computing	(Corbett & Hill, 2015)
R6	To Recruit and Advance: Women Students and Faculty in Science and Engineering	(National Research Council, 2006b)
R7	Unlocking Opportunity for African American Girls: A Call to Action for Educational Equity	(Smith-Evans, George, Graves, Kaufmann, & Frohlich, 2014)
R8	Why so few? Women in Science, Technology, Engineering, and Mathematics	(Hill, Corbett, & St. Rose, 2010)
R9	Stemming the Tide: Why women Leave Engineering	(Fouad & Singh, 2011)
R10	Women in Science and Engineering: Increasing Their Numbers in the 1990s	(National Research Council, 1991)
R11	Female Engineering Faculty at U.S. Institutions: A Data Profile	(Miller, 2014)
R12	From Scarcity to Visibility: Gender Differences in the Careers of Doctoral Scientists and Engineers	(National Research Council, 2001)
R13	Science and Engineering Programs: On Target for Women?	(National Research Council, 1992)
R14	Gender Differences at Critical Transitions in the Careers of Science, Engineering, and Mathematics Faculty	(National Research Council, 2010)
R15	Seeking Solutions: Maximizing American Talent by Advancing Women of Color in Academia: Summary of a Conference	(National Research Council, 2013)
R16	Broadening Participation in America's Science and Engineering Workforce	(Committee on Equal Opportunities in Science and Engineering, 2004)
R17	Changing America: The New Face of Science and Engineering	(Task Force on Women Minorities and the Handicapped in Science and Technology, 1989)
R18	Retention of Minority Students in Engineering	(National Research Council, 1977)
R19	Retention by Design: Achieving Excellence in Minority Engineering Education	(Landis, 2005)
R20	Community Colleges in the Evolving STEM Education Landscape: Summary of a Summit	(National Academy of Engineering & National Research Council, 2012)
R21	NSBE 2025: The Strategic Plan to Dramatically Shift the Face of Engineering by 2025	(Nelson & Reid, 2016)
R22	Realizing STEM Equity and Diversity Through Higher Education - Community Engagement	(Harkavy, Cantor, & Burnett, 2015)

R23	Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future	(National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2007)
R24	Surmounting the Barriers: Ethnic Diversity in Engineering Education: Summary of a Workshop	(National Academy of Engineering & American Society for Engineering Education, 2014)
R25	Colloquy on Minority Males in Science, Technology, Engineering, and Mathematics	(National Academy Of Engineering, 2012)
R26	Land of Plenty: Diversity as America's Competitive Edge In Science, Engineering, And Technology	(Congress & Commissions on the Advancement of Women and Minorities in Science, Engineering, 2001)
R27	Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads	(National Academy of Sciences, National Academy Of Engineering, & Institute of Medicine, 2011)
R28	Minorities: Their Underrepresentation and Career Differentials in Science and Engineering: Proceedings of a Workshop	(Dix, 1987)
R29	Proceedings of a Workshop for Program Directors in Engineering Education of Minorities	(National Research Council, 1976)

Appendix B: National report recommendations by category.

Table B1a: Practice & Policy: Practice – Students (K-12)

Recommendation	Report ID#
Teach girls that intellectual skills, including spatial skills, are acquired.	R8
Increase talent pool by vastly improving K-12 science and engineering education	R23
Improve preparation of teachers	R27
Spread the word about girls' and women's achievements in math and science.	R8
Work toward better gender balance of teaching staff.	R4
Explore how to spark the imagination of all young people to pursue science and engineering careers.	R17
Help girls recognize their career-relevant skills.	R8
Make videos, recordings and other entertainment and informational materials that awaken interest in science and engineering readily available to schools, libraries, museums and community groups, especially in low income areas.	R17
Promote success in school and the opportunities of science and engineering careers. Be sensitive to perpetuating the negative stereotypes of scientists and engineers.	R17, R29
Develop programs to increase minority awareness of the careers available to them through engineering	R29
Talented and gifted programs should send the message that they value growth and learning.	R8
Improve K-12 math and science education for underrepresented minorities	R27, R28
Encourage their children's interest in mathematics and science, through their own attitudes and actions.	R17
Encourage high school girls to take calculus, physics, chemistry, computer science, and engineering classes when available.	R8
Successful pre-college academic programs needed to increase academic skills of underrepresented minorities	R18, R21
Offer informal education programs for hands-on learning and academic support like tutoring, during school, after school, and over the summer.	R7, R17

Encourage children to develop their spatial skills.	R8
Be more accurate and honest with information about educational pathways	R20
Make engineering accessible and aspirational for children and communities of color	R21, R24
Prepare America's children by developing reading readiness, provide early math skills, and introduce concepts of creativity and discovery	R27
Provide a science and mathematics specialist in each elementary school, both to teach and to be a resource to other teachers.	R17

Table B1b: Practice & Policy: Practice – Students (Undergrads and Grads)

Recommendation	Report ID#
Dedicate resources for female and underrepresented minorities students (S&E dorms or women's S&E society, support programs)	R6, R8, R16
Modify curricula and teaching to better engage the interests of female students.	R6
Broadening scope of student services	R28
Minority engineering programs must be an integral part of the college of engineering	R29
Teach students clear management skills	R9
Emphasize real-life applications in early STEM courses.	R8
Properly train personnel involved in minority engineering programs	R29
Use results of test scores as guidance tools and not primary criteria in acceptance/rejection of minority students	R29
Comprehensive interventions should be targeted toward undergraduate women, U underrepresented minorities, and disabled students and implemented at the high school level, transition into post-secondary ed, and point where community college students move to 4-year institutions	R13, R26, R28
Brief appropriate officials on matters leading to the development of programs for women in science and engineering	R10

Table B1c: Practice & Policy: Practice – Professionals (Academia and Industry)

Recommendation	Report ID#
Consider programs targeting women S&E employees	R13
Value mentoring as important part of academic success and create programs for female students, female faculty/administrators, and other underrepresented groups.	R2, R3, R6, R8, R9, R14, R15
Women should band together to improve skills and performance levels and overcome built-in org barriers to learning and promotion	R13
Emphasize ways in which women can balance their personal lives and professional development. Offer work-life initiatives.	R2, R8, R9, R14
Provide mechanisms for ongoing interaction between mid-level and senior-level women and all levels of academia	R2, R15
Women should be given more incentives to seek employment in industry	R13
Ensure employees, specifically women, receive training and professional development.	R5, R9, R13, R26
Actively recruit women, underrepresented minorities and persons with disabilities into STEM majors and higher education faculty positions	R8, R17, R28, R29

Table B2a: Practice & Policy: Policy – National Level

Recommendation	Report ID#
Invest in downstream activities & create high-paying jobs (economic policy)	R23
Encourage federal agencies that grant funds to educational institutions to increase oversight and auditing of grantees to ensure compliance with Title IX in the STEM area, to ensure that girls and young women have equal access to STEM programs and curricula.	R7, R8
Promote federal and state policies that remove structural barriers to high-quality STEM learning	R21
Employ and design new policy levers that help STEM become more inviting and supportive of women, underrepresented minorities, and persons with disabilities at all levels	R16
Lay out clear guidelines, leverage their resources, and rigorously enforce existing laws to increase the science and engineering talent developed in this country.	R1
Improve access to all postsecondary education	R27
Vote for elected officials with a proven commitment to education.	R17

Table B2b: Practice & Policy: Policy – Local Level

Recommendation	Report ID#
Develop programs of positive incentives for faculty who retain graduate students and work with minority engineering students	R13, R19
Establishing flexible-time policies such as family leave, flex time, part- time tenure, and temporary stoppage of the tenure-clock; and, just as Importantly, an atmosphere that allows faculty members to take advantage of these policies without fearing damage to their careers.	R3, R10, R12, R13, R17
Ensure employee roles, responsibilities, and paths towards advancement are clearly defined.	R5, R8, R9
Work with their faculties and department chairs to examine evaluation practices to focus on the quality of contributions and their impact.	R1
Ensure untenured women faculty are indeed reviewed by their peers during probationary period and that every tenure-review committee has at least one female member	R13
Make performance standards and expectations clear.	R8, R17, R26
Look at the definition of academic success in the appointment, promotion, and tenure process.	R2
Enforce Title IX in science, technology, engineering, and math	R8

Table B3a: Culture & Climate: Culture

Recommendation	Report ID#
Make US most attractive setting to study and perform research	R23
Professional role models needed to direct "masculine" professions to young women and "feminine" professions to young men.	R4
Send an inclusive message about who makes a good science or engineering student.	R8
Think strategically about message leadership sends out regarding women in science.	R3
Redesign institutions to work for minority students	R19, R27
Create an organizational culture that values employees' contributions and respects all.	R9
Ensure that their practices—including rules and regulations—support the full participation of women and do not reinforce a culture that fundamentally discriminates against women.	R1

Provide clear leadership/policies in changing the culture and structure of their institutions to recruit, retain, and promote women/students (including minority women) into STEM classrooms, faculty and leadership positions; and then dedicate resources to that mandate.	R1, R6, R7, R13, R17, R24
Recognize and publicize successful students and teachers as a way to encourage others. Likewise, spread stories of successful women, minorities and people with disabilities in science and technology in order to in- crease the visibility and attractive- ness of these careers to all young people	R17, R21
Develop activities that will enhance the awareness, cooperation, and support of members of the engineering and academic communities for minority engineering initiatives	R29

Table B3b: Culture & Climate: Bias and Discrimination

Recommendation	Report ID#
Examine equity issues like salary, tenure process, or climate - periodically	R2, R6, R9, R14, R15
Examine their entire review process, including the mechanisms by which decisions are made to send a submission to review, and take steps to minimize gender bias, such as blinded reviews.	R1
Training people to see and identify unexamined bias in their own and others' actions.	R3, R7, R17, R24
Changing the context of test-taking to eliminate stereotype threat.	R3
Encourage editorial boards of societies to ensure their boards reflect demographics of their memberships	R2
Review their nomination and election processes to address the underrepresentation of women in their memberships	R1
Establish an Office on the Status of Women Faculty Members with senior female professor as director, with line responsibility to the chief administrative officer of the campus	R13
Promptly address sexual harassment in schools, particularly in classrooms where female students are underrepresented and are likely to feel unwelcomed even absent negative messages form their teachers or peers.	R7
Take responsibility for creating a productive environment and immediately implement programs and strategies shown to be successful in minimizing the effect of biases in recruiting (students and professionals), hiring, promotion, and tenure.	R1, R6, R18
Using new metaphors and descriptions to discuss bias and educate (students, school personnel, faculty, admins, etc.), in particular calling bias or stereotyping unexamined places the responsibility on the person who holds or acts on the bias or stereotype.	R3, R4, R7, R8
Restructuring hiring and promotion procedures to reduce bias and encourage diversity, particularly the training of search committees, deans, and department chairs to recognize and reduce bias in hiring, evaluation and promotion, and have women apart of the process.	R3, R6, R14, R24
Take steps necessary to encourage adequate enforcement of anti-discrimination laws, including regular oversight hearings to investigate the enforcement activities of the Department of Education, the Equal Employment Opportunity Commission, the Department of Labor, and the science granting agencies	R1

Table B4a: Information & Knowledge: Collecting and Disseminating Data

Recommendation	Report ID#
Collect better data on women and underrepresented minorities, minority engineering programs in S&E	R2, R15, R16, R17, R29
Collect data on recruitment and retention	R2, R23, R25
Collect data on the career tracks of their members	R14
Take lead in developing specific national education goals, performance standards, and timetables needed for meeting them	R17
Fostering the development of freer measures of labor force adjustment, including tracking career paths of postdoc personnel	R10
Require schools and districts to annually report enrollment in STEM courses (K-12), disaggregated by race/ ethnicity, grade level, special education status, and English Learner status.	R7
Disseminate the data on recruitment, retention, and participation of women in science and engineering to people in academe, government, industry, and professional societies	R2, R10, R14, R29

Table B4b: Information & Knowledge: Reliable Measures of Assessment

Recommendation	Report ID#
Assess what else can be done and develop interventions for both women and men	R13
Monitor undergraduate student progress to assess where "losses" of S&E women and minorities occur	R13, R15, R18, R29
Monitor the progress of efforts to increase the participation of women in scientific and engineering careers, through workshops and conferences	R10, R17
Identify and report effective educational programs, curricula, schools and best practices for recruitment and retention in STEM	R10, R12, R15, R17, R18, R20, R21, R24, R25
Encourage the development of reliable outcome measures to assess the specific contributions of programs that enhance the flow of women into S&E careers	R10, R16, R29

Table B4c: Information & Knowledge: Areas of Inquiry

Recommendation	Report ID#
Stimulate research on issues relevant to women scientists and engineers, by establishing study panels that can explore some subset of these issues in greater depth	R10
Further inquiry around areas affecting women and underrepresented minorities in science and engineering	R11, R12, R14, R25, R28
Conduct research that considers interaction of gender in international context in chemistry, math, and computer science worldwide.	R4
More qualitative approaches to research on younger boys of color	R25
Research on undergraduate students is necessary coupled with an understanding of precollege experiences that do or do not adequately prepare African American males for pursuing STEM study and careers	R25
Study ways technical and vocational programs in secondary school can be strengthened	R29
Utilize detailed historical perspectives of institutions, professional societies, and disciplines when examining the participation of women in higher education in various countries.	R4
Clear conceptualization of challenges and positive factors that impact academic success of minority males in STEM	R25

Better understand how social and cultural capital develop and manifest in the academic and life trajectories of males of color and the multiple dimensions of identity among males of color at this level.	R25
Search, develop, evaluate, revise, and disseminate models in career development, mentoring, and recruiting and advancement.	R2, R13, R15, R25
Enhance research capacity and research opportunities at Tribal colleges to advance Native Americans in STEM	R16
Investigate why female faculty, compared to their male counterparts appear to continue to experience isolation in subtle and intangible ways	R14

Table B5a: Investments & Commitments: Funding

Recommendation	Report ID#
Provide financial support for financial aid programs and intervention programs designed to increase the number of women, minorities and people with disabilities who complete training in mathematics, science and engineering.	R17, R18, R26, R27, R28
Continued or enhanced funding of research into social and institutional structures and field testing of methods to reduce bias and stereotype threat.	R3, R24
Specific funding sources should be targeted at undergraduate women	R13
More scholarships should be offered in science and engineering, as well as in science and mathematics education.	R17
Devote long-term, sustained effort to supporting education.	R17
Need for funding longitudinal evaluations of selected programs	R13, R25
Ensure adequate funding levels for each school district in their state.	R17

Table B5b: Investments & Commitments: Collaboration

Recommendation	Report ID#
Focus attention on the role of community colleges and other institutions whose mission focuses on workforce prep and minority engineering enrollment	R16, R29
Coordinate transfer programs from 2-year to 4-year institutions to increase the number of 2-year college students going on to earn bachelors' degrees in science and engineering.	R17, R24
Build partnerships with parents to help students set high career goals and complete rigorous coursework	R17
Extend and engage in outreach for underrepresented students at both K-12 and undergraduate levels.	R6
Compile directory of businesses, orgs, agencies, foundations that support minority engineering efforts	R29
Provide summer work and research opportunities to teachers and to high school students	R17, R18, R29
Establish collaborative and formal relationships with local high schools	R29
Co-op programs with industry and government should work more closely with minority engineering program directors	R29
Strengthen university-industry partnerships	R9, R17, R24, R29
establish consortia of various stakeholders when developing engineering or science track in high schools	R29
Motivate their employers to donate equipment, money, and personnel to their children's school.	R17
leverage professional societies and organizations	R24, R29
companies should expand the universe from which they recruit entry-level employees	R13
Become involved, by offering to support their local public schools, teachers, and students.	R17

Establish/help establish an Engineers' Speakers Bureau	R29
Promote collaboration and interaction among societies.	R2
Participate in community projects that guide our young people toward success in school and careers in science and engineering.	R17
Establish a National Research Scholars Program in Science and Engineering which enables high school students to have early research experiences and go on to earn bachelors' degrees in science and engineering.	R17
Develop local coalitions of community leaders, businesses, educators and government officials to improve education, particularly in mathematics and science.	R17
Encourage members of underrepresented groups to become scientists and engineers, through serving as a tutor, mentor or role model.	R17
find or setup a body representing the public, nonprofit, and private sectors that would coordinate efforts to transform the image of the STE professions	R26
There's a need for an ongoing, global learning community focused on STEM diversity	R22
Mentoring and role modeling could be expanded to encompass colleagues and partners in business and industry	R20
developing a program of studies to facilitate the positive employment opportunities related to diversification in the workplace	R10

Table B6: Miscellaneous

Recommendation	Report ID#
Recognize psychology as a STEM discipline	R15
Offer financial support for the development of training materials for departments of psychology that help promote better climates for WOC	R15
Offer financial incentives to institutions and departments of psychology to develop comprehensive programs to support WOC	R15
Make laboratories accessible and adapted to persons with disabilities.	R17
Treat every student with a physical disability as a potential scientist or engineer, and provide the necessary technical aids to minimize physical obstacles.	R17

Appendix C: National report by decade and theme.

	Report by Decade				
	1970s	1980s	1990s	2000s	2010s
Practice - Students (K12)	18,29	17,28		23	4,7,8,20,21,24,27
Practice - Students (Undergrad & Grad)	18,29	28	10,13	6,26	8,9
Practice - Professionals (Academia & Industry)	29	17,28	13	2,3,6,26	5,8,9,14,15
Policy - National		17		1,16,23	7,8,21,27
Policy - Local	29	17	10,13	1,2,3,12,26	5,8,9
Culture & Climate - Culture	29	17	13	1,2,6,19,23	4,7,8,9,21,24,27
Culture & Climate - Biases & Discrimination	18	17	13	1,2,3,6	4,7,8,9,14,15,24
Information & Knowledge - Collect and Disseminate Data	29	17, 28	10	2,16,23	7,14,15,25
Information & Knowledge - Reliable Measures of Assessment	18,29	17	10,13	12,16	15,20,21,24,25
Information & Knowledge - Areas of Inquiry	29	28	10, 13	2,12,16	4,11,14,15,25
Investments & Commitments - Funding	18	17,28	13	3,26	24, 25, 27
Investments & Commitments - Collaboration	18, 29	17	10, 13	2,6,16,26	9,20,22,24
Miscellaneous		17			15