Final Report on NSF MSP/RETA "Promoting Institutional Change to Strengthen Science Teacher Preparation" Grant #0831950

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Association of Public and Land-grant Universities

Jennifer B. Presley and Kacy Redd
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Principal Investigator	Howard Gobstein, A·P·L·U
Co-Principal Investigator	Charles R. Coble, Third Mile Group
Co-Principal Investigator and Project Director	Jennifer B. Presley, A·P·L·U
Associate Project Director	Kacy Redd, A·P·L·U

ASSOCIATION OF PUBLIC AND LAND-GRANT UNIVERSITIES
1307 New York Ave. NW Suite 400 | Washington, DC 20005

ASSOCIATION OF PUBLIC AND LAND-GRANT UNIVERSITIES
SMTI
Science & Mathematics Teacher Imperative

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I. Executive Summary

Context for the Grant

In 2007, the Association of Public and Land-grant Universities (APLU) developed the Science and Mathematics Teacher Imperative (SMTI), a commitment to increase the quantity, diversity and quality of the science and mathematics teachers member universities produce. This commitment assumed an important role for the leaders of major public universities to embrace science and mathematics teacher preparation as a core component of their institutions' missions. The size and breadth of these institutions provide a unique opportunity to place a large number of students into classrooms having the highest quality preparation in their disciplines.

This RETA grant entitled "Promoting Institutional Change to Strengthen Science Teacher Preparation," tested a theory of action that institutional change could be enhanced both by top leadership commitment and faculty ownership of the actions. We posited that APLU could affect the first, since it is a membership organization of presidents and provosts. Collaboration with the American Physical Society and the American Chemical Society was intended to promote faculty participation.

Design of the Project

Twenty seven institutions committed to SMTI were selected to participate in ''The Leadership Collaborative" (TLC). Each institution designated a Team Leader with a team consisting of faculty from science and mathematics as well as education, university administrators and K-12 representatives. APLU implemented a set of activities designed to galvanize institution leaders, encourage cross-college and cross-institution collaboration, and promote strategic thinking with regard to institutions' science and mathematics teacher preparation programs. Additional activities included: convening three learning communities; identifying promising/exemplary practices in teacher preparation; and seeking consensus on the characteristics of quality teacher preparation programs that included interviews with national experts and focus groups with disciplinary faculty in the sciences and mathematics.

A grant supplement was awarded to support the completion of the Analytic Framework – a taxonomy of design and innovation for STEM teacher preparation and development. This tool was used throughout the project to frame participants' plans, to guide the promising/exemplary practices pilot, and to provide implementation strategies for Ten Key Questions that emanated from the program-quality initiative.

Outcomes

- TLC participants reported that their most successful outcomes were strengthened cross-college collaborations (20/23) and engaged university leadership (16/23).
- Half the participating institutions increased science & mathematics teacher production or enrollment. The average production growth for TLC participants outpaced other APLU/SMTI institutions that were not part of the TLC project.
- Nine (9) institutions accomplished campus-wide change, five of which were the only institutions to identify APLU's efforts to galvanize institutional leadership as the most important thing the association did.

- All but two institutions with campus-wide change and program-restructuring (6) indicated that their university leadership was involved or supportive of their change efforts. For those institutions that implemented program improvements only, the majority did not make reference to their university leadership being involved.
- Institutions that were less advanced in their reform efforts at the beginning of the project found the participation of disciplinary societies to be more helpful.
- Two other aspects of the project were highly valued by The Leadership Collaborative. Almost all participating institutions (22/23) referenced creating opportunities for institutions to learn from one another as being valuable. Raising the status of teacher preparation locally and/or nationally was also important to many (18/23).
- Seven research reports provide practical approaches to program quality and institutional change.

Conclusion

We have demonstrated that a national association in concert with member universities and disciplinary societies can raise the status of science and math teacher preparation on campuses. APLU analysis supported by WestEd's evaluation point to two key project components as major contributors to overall success:

1. **Institutional Leaders will engage when**

    - The work is part of a national effort of similar institutions;
    - Provided opportunities to gather together along with their own team leaders, and at other meetings to learn and share; and
    - Involved in the process on their campuses.

    About two-thirds of the institutions had active, unprecedented involvement from provosts, which led to more and/or different than usual efforts. A prevalent change was the ability of provosts to leverage broader participation across colleges and departments, particularly crossing the sometimes challenging boundaries between education colleges/departments and those housing the STEM disciplines. The impact of senior leaders was most clearly felt by those institutions that achieved campus-wide change.

2. **APLU's project design created opportunities for collaboration and institutional change by including**

    - The APLU project imprimatur of this national issue enhanced campus efforts;
    - Institutional Implementation and Assessment Plans for work as part of this project;
    - Annual national project gatherings;
    - Cross-college teams within institutions fostered collaboration with opportunities for team leaders to generate their own communities of study and action; and
    - The Analytic Framework, prompting new ideas about changing STEM teacher preparation, particularly for recruitment.

A list of publications with URLs is provided in Attachment 1. A diagram showing project relationships is provided as Attachment 2.

II. Context for the Grant

In 2007, the Association of Public and Land-grant Universities (APLU) developed the Science and Mathematics Teacher Imperative (SMTI), a commitment to increase the quantity, diversity and quality of the science and mathematics teachers member universities produce. This commitment assumed an important role for the leaders of major public universities to embrace science and mathematics teacher preparation as a core component of their institutions' missions. The size and breadth of these institutions provide a unique opportunity to place a large number of students into classrooms having the highest quality preparation in their disciplines.

SMTI was formalized at the APLU Board of Directors meeting on November 9, 2008, and 132 member institutions and 13 systems have joined the Imperative to date. Four SMTI national annual meetings have been held, the first in Boulder on May 17-18, 2009, in which 75 institutions participated, the second in Cincinnati on June 6-8, 2010, with 70 institutions participating, the third in Portland, Oregon on June 8-10, 2011, with 75 institutions, and the fourth in Alexandria, Virginia on June 6-8, 2012, with 68 institutions.

As part of the SMTI initiative, the NSF-supported RETA grant entitled "Promoting Institutional Change to Strengthen Science Teacher Preparation", under the auspices of its Math and Science Partnership program, is providing a focused pilot study based on the theory of action that institutional change depends both on top leadership commitment and faculty ownership of the actions. APLU brings the first, since it is a membership institution of presidents and provosts. Collaboration with the American Physical Society was established as a grant partner, and the American Chemical Society has been included in each grant activity to help build support for the creation of the Chemistry Teacher Education Coalition (CTEC) – a chemistry equivalent of the initiative in the physics community to address physics teacher education, the Physics Teacher Education Coalition (PTEC).

In Year 1 of the grant, 27 institutions were selected from those who had joined SMTI to participate in The Leadership Collaborative (TLC). Arizona State University dropped out due to changes in institutional organization and leadership. The University of Illinois Urbana Champaign also became an inactive member in 2010. The 25 remaining participating institutions are:

Auburn University	University of Cincinnati
Boise State University	University of Colorado at Boulder
California State University, Fullerton	University of Houston
Florida International University	University of Iowa
Georgia State University	University of Kansas
Indiana University-Purdue University Indianapolis	University of Kentucky
Lincoln University	University of Maryland, College Park
Michigan State University	University of Minnesota-Twin Cities
Portland State University	University of New Hampshire
South Dakota State University	University of North Carolina at Charlotte
Stony Brook University, SUNY	University of Texas at San Antonio
University of Arkansas, Fayetteville	University of Wisconsin-Milwaukee
University of California, Santa Barbara	

III. Major Accomplishments in First Three Years of the Project

Year 1: In the first year of the project, major actions included

- Selecting participating institutions. An external selection panel reviewed voluntary applications from 61 SMTI institutions using criteria provided in advance, including that the group reflect quite closely APLU's membership by Carnegie Classification, geographic distribution, at least one institution from each of the five largest states, at least 2 minority-serving institutions, demonstration of top leadership commitment, and Team Leaders from central administration.
- Establishing the collaboration with the American Physical Society. In March 2009 a workshop in Pittsburgh in conjunction with the Physics Teacher Education Coalition (PTEC) meeting gave participants an opportunity to learn about what the physics community is doing to strengthen physics education. The workshop reinforced the importance of disciplinary faculty participation in teacher preparation through discipline-based education research (DBER) and reform of undergraduate education.
- The first TLC workshop extended the SMTI National Conference. Eighty eight (88) people from TLC institutions attended, including at least one from each TLC institution. This gathering began to establish the ongoing relationships that grew throughout the project.
- WestEd began collecting formative evaluation data by interviewing each Team Leader.
- A special group discussion was convened for TLC Provosts at the annual APLU Chief Academic Affairs Officers' meeting.

Year 2:

- Participants developed and submitted Implementation and Assessment Plans (IAPs) using the Analytic Framework as a template for identifying particular strategies that would address recruitment, program design and institutional policies and practices that would strengthen the quantity, quality and diversity of students in their science teacher preparation programs. They were also asked to provide measures against which they could monitor their own progress over the period of the grant and on into the future. The process was designed to provide maximum value added for institutions' own work.
- In order to facilitate communication and understanding between TLC Team Leaders and their institutions' Provosts, a three-day retreat was convened in Miami. All but two Team Leaders and 15 provosts were in attendance. Two external higher education change experts (Ann Austin, Michigan State University; Ellen Chaffee, Association of Governing Boards) introduced rubrics for successful change efforts. WestEd evaluated the retreat and found a very positive response. Indeed, the impact of this retreat continued to be identified throughout the remainder of the project. It was reported to be one of the most effective activities that APLU undertook. A report on the retreat is available (Frank and Shapiro, 2010a).
- The partnership with APS continued with senior staff participating in various TLC activities, including the Miami retreat. Five TLC participant team members were sponsored to attend the annual PTEC meeting, with membership in PTEC (two joined) a condition of support. The American Chemical Society's interest in initiating CTEC (Chemistry Teacher Education Coalition) was promoted by providing opportunities for discussion at TLC-sponsored meetings.
- A survey of STEM organizational structures and faculty appointments was undertaken. Twenty-three TLC institutions responded. Data were compiled on teacher certification, pedagogical instruction and STEM discipline-based education research, faculty appointments, STEM centers and faculty reward systems. A report is available (Frank and Shapiro, 2010b).

- A second Team Leaders' meeting was convened preceding the annual SMTI National Conference. During the meeting Team Leaders discussed themes and interests that would help to expand their horizons beyond their internal campus work with IAPs. A process to identify and convene several Learning Communities was undertaken in Year 3 as a result of these discussions.
- A second special group discussion was convened for TLC Provosts at the annual APLU Chief Academic Affairs Officers' meeting.
- Data collection on teacher production and targets, annual reports in IAPs, and WestEd's formative evaluation continued.
- A grant supplement was received to continue the work of finalizing *The Analytic Framework: A taxonomy of design and innovation for STEM teacher preparation and development*. An on-line version was piloted, and a meeting hosted in Washington, D.C. of directors of state and national programs offering intensive pre-service and in-service research experiences for teachers to share knowledge and recommend changes in the Analytic Framework to reflect emerging trends in STEM preparation and development. Others provided critiques of the emerging *Framework*. Discussions began regarding the development of a rubric to assess institutional status and change aligned with the Analytic Framework goals and strategies. Proto-type technical assistance visits were initiated.

Year 3:

- Participating institutions submitted annual updates to their Implementation and Assessment Plans. An external consultant who reviewed these progress reports recommended providing more specific guidance when final reports were requested in the final year of the project since these interim reports were quite varied in detail, timelines, and how to describe practices.
- Upon the recommendation emanating from the Year 2 Team Leaders' meeting, TLC Learning Communities (LC) were established. A letter calling for participation to serve on one of seven learning communities was issued. After all nominations were received, three topics emerged as ones that garnered volunteers for the effort. Each group of eight from different institutions then had a fly-in organizing meeting, and was provided with a small budget for convening in-person meetings. Team Leaders acted as co-chairs to each LC.
    - The first LC on professional learning communities for pre-service teachers completed its deliberations with a presentation at the TLC Workshop that preceded the SMTI National Conference.
    - LC #2 on common core state standards in mathematics and science issues a report entitled *Discussion Paper on Common Core State Standards and Teacher Preparation: The Role of Higher Education* (APLU, 2011). This was also presented at the TLC Workshop and was followed by a national forum/webcast in Washington, D.C. during Year 4.
    - LC #3 on improving STEM undergraduate education in a faculty context undertook a research project to identify whether there were common organizational threads that were leading to the successes at the assembled institutions. Two reports are detailed in the Year 4 report that follows this section.
- A third Provosts' discussion was convened at APLU's Chief Academic Affairs Officers' meeting.
- Teacher production data was again collected, and WestEd undertook another year of formative evaluation.
- The work on the Analytic Framework that was supported by the supplement was completed. Coble (2012a) describes the development of the Framework, and Coble et al. (2012) provides the Framework.

IV. Year Four Activities

First Major Action: Final Reports from 23 Institutions

As planned and documented in the Year 3 report, we provided a template to each of the remaining 25 Team Leaders for their final cumulative report to APLU. We sent the survey to the Team Leaders on April 2, 2012 with a due date of April 16, 2012. The last survey was returned June 21, 2012. We received 23 of the 25 requested reports. Survey Questions are provided in Attachment 3. The final reports were reviewed, answers distilled, and common themes or core ideas across the institutions were identified (Redd, 2012).

Key Results: Institutions provided their most successful outcome, with an option to include a second one (question 1), as well as outcomes in question 3 and 4 of the survey. The results are shown in Table 1.

The successful outcomes most often cited by the institutions were

- **strengthened cross college-collaborations (20 of 23)**
- **engaged university leadership (16 of 23)**

In addition, half of the institutions reported that they had an increase in teacher production or enrollment as their most successful outcomes. Two institutions became UTeach sites, with one of these institutions also establishing a STEM education center. In all, four institutions reported establishing (or receiving a significant increase in support, including permanent space and funding for two postdoctoral fellows) or strengthening a STEM education center. Lastly, one institution established a university-wide STEM education council for teacher preparation, with faculty and associate and assistant deans from all colleges. The most significant barriers related to lack of resources, including funding and release time. This NSF grant was not designed to provide such support to participating institutions. But we note that much was accomplished despite the perceived barriers.

Table 1. Most Successful Outcomes and Barriers for The Leadership Collaborative

	Number of Institutions
Most Successful Outcomes	
Strengthened cross-college collaborations	20
Engaged university leadership	16
Increased teacher enrollment/production	12
Implemented new recruitment strategies	12
Increased external funding	10
Created (or increased support for) STEM Education Centers	4
Became a UTeach site	2
Established a university-wide STEM education council for teacher preparation	1
Barriers	
Lack of resources, including funding and release time	13
Department culture and/or resistant departments	6
Local and state economic realities such as hiring, firing, and pay for teachers	5
Turnover in leadership	4
Campus policies and priorities	3

From the remaining questions in the final reports, we found that:

- APLU's engagement of university leaders helped institutions accomplish their goals to improve science and mathematics teacher preparation;
- APLU's promotion of the importance of teacher preparation aided institutions' work;
- Participation in a project that includes faculty facing similar challenges from other universities promotes institutional change;
- For some institutions, having a common framing tool and external accountability helped stimulate activity.

Conclusion: The structured survey for year four facilitated aggregate analysis across institutions, and enhanced our ability to draw conclusions about project outcomes. We found that APLU did indeed galvanize university leadership with particular effect at some TLC institutions. Calling upon participants to create cross-college teams was particularly effective in helping to increase cross-college collaboration. We provide a more detailed account of how these data relate to project outcomes, and help to inform our primary and supporting research questions in Section IV on Research and Evaluation in this report.

Second Major Action: Partnering with Disciplinary Societies

Documenting the history of the American Physical Society's involvement in education. As part of the partnership with the American Physical Society (APS), APLU contracted in year 4 with the disciplinary society to document how and why APS became involved in physics education reform as a possible guide to other disciplinary societies interested in seeding reform for STEM education in their discipline. Popkin (2012) describes APS' evolving commitment to education reform.

Popkin reports that early in its history, APS focused on promoting physics research, publishing journals, and organizing meetings. As early as 1915 the Society did appoint a committee "to consider how the Society can be made useful to teachers in colleges and secondary schools,'" but APS generally declined to address educational and pedagogical issues except in marginal fashion.

In the 1980's this began to change with the creation of APS' Department of Education and Outreach, which was in response to a growing awareness of educational problems facing the nation. One of the projects of this new department was a reevaluation of introductory undergraduate physics curriculum, which forged a partnership between the American Association of Physics Teachers (AAPT – which had spun off from APS in 1930), the American Institute of Physics (AIP), and APS.

Other milestones include:

- In 1990 APS created the Forum on Education. Nearly 10% of APS's total membership are members and is one of the Society's largest units.
- In 1993 a new Executive Director was hired with an explicit mission to develop partnerships with AAPT and expand APS's educational activities.
- Creation of the Teacher-Scientist Alliance Institute (TSAI) – involving scientists and engineers in K-12 education.
- During the 1990's, New Faculty Workshops were introduced that provided professional development in teaching to early career physics and astronomy faculty. Additionally, APS held biennial department chair conferences on education related themes.

- In 1999, PhysTEC was formed, and the APS council adopted a policy that physics education research as a sub-discipline of physics should be considered by the same criteria of scholarship as other areas of physics research.
- In 2003, APS released a report titled *Strategic Programs for Innovations in Undergraduate Physics (SPIN-UP)*, which remains the seminal text for departments seeking to improve their programs and recruit and retain majors.
- In 2005, APS created the *Physical Review Special Topics: Physics Education Research (PRST-PER)*, a journal devoted to research in physics education.

Communication and Dissemination: APLU has participated in APS and AAPT programs.

- 2012 Physics Teacher Education Coalition Conference, Ontario, CA. February 3, 2012. *University Leader Support for Sustained Reform in Science Teacher Education.* Moderator: Howard Gobstein; Panelists, Al Bennett, Dean, School of Biological Sciences, University of California, Irvine; Jane Conoley, Dean, Gervirtz Graduate School of Education, University of California, Santa Barbara, and Michael Gottfredson, Provost, University of California, Irvine (now President, University of Oregon).
- American Association of Physics Teachers (AAPT) Winter Meeting, Ontario, February 7, 2012. *Education Policy Symposium Panel*. Panelists were Helen Quinn, Professor Emerita of the Department of Particle Physics and Astrophysics at the SLAC National Accelerator Laboratory, and Co-chair of Stanford University's K12 Initiative; Howard Gobstein; Pat Heller, Associate Professor of Curriculum and Instruction at the University of Minnesota and a founding member of the Physics Education Research Group.

Third Major Action: Completing the Work of TLC Learning Communities

In 2010 APLU established a process to identify and populate several participant-identified Learning Communities that would consider issues relevant to "promoting institutional change to strengthen science teacher preparation." Most of the work was accomplished during Year 3 of the project and a complete description of how the learning communities were established is provided in that year's annual report. What was left to be accomplished was to disseminate outcomes of one (Learning Community #2), and complete data analysis, report writing, and dissemination for another (Learning Community #3).

Learning Community #2: Common Core State Standards in Mathematics and Science

This group wrote a synthesis/analysis paper that outlined recommendations for how higher education could actively contribute as the Common Core State Standards move forward (APLU, 2011).

Communication and Dissemination: On October 13, 2011, APLU held a forum to feature the release of the *Discussion Paper on Common Core State Standards and Teacher Preparation: The Role of Higher Education* co-written by W. Gary Martin, Leischuck distinguished professor, mathematics education at Auburn University and Suzanne Wilson, university distinguished professor and chairperson, teacher education, Michigan State University.

Stephen Pruitt, vice president, content, research and development, Achieve, opened the forum by looking forward to the development of the next generation science standards. At the Forum, Wilson noted that the Common Core State Standards for Mathematics (CCSS-M) represent an

unprecedented and unified effort to promise U.S. children a high quality, focused mathematical and scientific education on core topics across all states, and to use high-quality, aligned assessments to track student progress over time. To meet these critical goals for teacher preparation, Wilson said that higher education institutions have a key role to play in providing leadership to ensure a proper balance between immediate action and long-term collaboration that supports collective work. Three examples cited were:

- Aligning higher education curriculum with K-12 curriculum, which includes both adapting admissions standards and revising curricula of first-year courses that act as bridges between K-12 and college majors;
- Preparing and educating teachers, both prospective and practicing, which includes revising curricula in disciplinary departments to prepare teachers to teach the Common Core, revising professional preparation coursework and experiences, and working in partnership with professional development programs; and
- Conducting research on issues of teaching and learning the Common Core State Standards, teacher quality, and the implementation of the Common Core State Standards.

The forum recording is available: https://www.aplu.org/sslpage.aspx?pid=2153.

During this forum and as a response to the paper's call to action, SMTI announced a new program that highlights higher education's role related to the Common Core State Standards for Mathematics. The Mathematics Teacher Education Partnership, or MTE-Partnership, focuses on preparing high-quality secondary mathematics teachers who are ready to teach the new, more rigorous standards.

Next Steps: APLU has received a separate NSF grant (# 1147987) to convene the Mathematics Teacher Education Partnership and is seeking funding to undertake its agenda. The group presently consists of 38 partnership teams containing 87 school systems, 68 universities and 9 community colleges across 30 states. Its goal is to transform the preparation of secondary mathematics teachers to ensure teacher candidates can promote mathematical excellence in their future students, leading to college and career readiness as described in the CCSS-M and other documents.

The Partnership is developing a coordinated research, development, and implementation effort based on the "Networked Improvement Community" (NIC) model developed and promoted by the Carnegie Foundation for the Advancement of Teaching which is serving as a design partner.

Learning Community #3: Improving STEM Undergraduate Education in a Faculty Context

During year 3 of the project, eight TLC Learning Community members worked together to study how undergraduate STEM education could be improved for all students while attending to the realities faced by STEM faculty. The group decided to take advantage of the rich experiences that were represented by the assembled team by creating a mini research project that would try to identify whether there were common threads that were leading to the successes at the assembled institutions. Jana Bouwma-Gearhart, an expert in organizational change analysis, was tasked with designing a research protocol that included site visits to five of the institutions (Florida International University, University of California Santa Barbara, University of Colorado Boulder, Boise State University and Portland State University.) Two research papers were published by APLU in 2012. Summaries follow:

Improving Postsecondary STEM Education: Strategies for Successful Collaboration and Brokering Across Disciplinary Paradigms. Jana Bouwma-Gearhart, Kristen H. Perry and Jennifer B. Presley. APLU/SMTI Paper 4, 2012.

Key Results: Five strategies emerged across the institutions for successful postsecondary education collaborations

1. Successful collaborations recognize that those involved in postsecondary improvement activities are at different points in their appreciation of interdisciplinary work and the value of others' expertise.
2. Successful collaborations occur when participants recognize that faculty and instructors are likely to be on numerous paths and at different points in their careers with respect to pedagogical issues and experience with education reform.
3. Successful collaborations recognize the critical role of literacy brokers of education research and theory in the collaboration.
4. Successful brokers frame education research and theory in relation to typical STEM research and teaching practices and acknowledged expertise.
5. Formal interdisciplinary collaborative faculty groups help catalyze institutional change.

Conclusion: In order to best drive widespread change and improve postsecondary education, it is critical to identify and empower individuals who can act as brokers between seemingly disparate disciplines in terms of research, theory, and practices and norms, and who can do so in ways that support and capitalize on the diverse experiences and expertise each individual brings to the table.

Engaging STEM Faculty While Attending to Professional Realities: An Exploration of Successful Postsecondary STEM Education Reform at Five Science & Mathematics Teacher Imperative Institutions. Jana Bouwma-Gearhart. APLU/SMTI Paper 5, 2012.

Key Results:

1. Structural supports including external supports, such as financial supports from the institution; financial supports from respected organizations; providing convening space, and utilizing teaching tools in ways that conserve time.

2. Policies and practices that attend to issues of hiring, promotion and tenure. Unique hiring practices and positions held great promise for interviewees and are described in the paper. Many spoke with enthusiasm about the prospect of a new generation of faculty who is gaining a much deeper understanding of STEM pedagogy in undergraduate and graduate school as a result of their involvement in education reform and the opportunity to learn from teaching experts.

3. Fostering STEM faculty participation and interdisciplinary collaboration. Extrinsic factors are important in motivating additional STEM faculty and instructor participation. These include the influence of strong department chairs and deans and other respected STEM colleagues, financial motivation, affiliations with prestigious grants and disciplinary organizations, and the prestige and safety often secured via an already-established and distinguished reform group.

   Four stages of evolution through which STEM faculty progress as they gain understanding and appreciation for education research and theory, and their Education unit colleagues, were identified. These were initial suspicion, followed by awareness and

respect for other types of knowledge, then acknowledgement of the values of others' research, and finally, the acceptance of education research as an area of expertise, and its researchers as experts.

4. The need for common focus. STEM reform collaborations are best built around specific foci. Strategies to support the selected focus included the use of data, building synergy with related reform initiatives, and using education theory and research to inform the selected effort.

5. Re-envisioning power towards change. Both explicit, or positional power, and "hidden" power were documented as important for change. Those who made the reform efforts really take hold usually held less traditional positions, especially those in novel faculty positions, and Education faculty with strong STEM training. Even postdoctoral fellows and Learning Assistants had collective power to promote reform efforts. Influential and esteemed faculty were also influential. Most influential were those whose disciplinary education, research and theory expertise and communication skills rose to the level of "literacy broker". These individuals could translate education, research and theory into a form that was understandable and usable by STEM faculty and instructors, and speak the language of STEM with respect to disciplinary ways of knowing and processes.

Conclusion: The approaches detailed in this report provide new insights and confirm others about how to promote institutional change to foster undergraduate education (and by extension teacher preparation) reform through faculty participation. Many are low cost solutions, and all represent pragmatic practices that provide existence proof that reform is well under way among faculty in research-focused universities, and is becoming integrated into their professional cultures.

Communication and Dissemination: We announced and distributed the two Bouwma-Gearhart papers (Bouwma-Gearhart, 2012; Bouwma-Gearhart, Perry, and Presley, 2012) at the APLU Annual Meeting in Denver, Colorado on November 11, 2012 as part of a panel discussion on *Improving STEM Teaching and Learning: Leveraging STEM Education Centers.* STEM education centers have been identified as a possible lever of change at research universities (Bouwma-Gearhart, 2012). The session was introduced by Jennifer Presley, and panelists included: Noah Finkelstein, Professor, Physics, University of Colorado, Boulder; Kenneth G. Furton, Dean, College of Arts and Sciences, Florida International University; and Mary John O'Hair, Dean, College of Education, University of Kentucky – all TLC member institutions. The session was moderated by President Edward Ray of Oregon State University.

The two papers have been added to the APLU/SMTI website, and Bouwma-Gearhart is seeking publication in academic journals.

Conclusion: Our decision to allow Team Leaders to create their own Learning Communities on chosen topics in Year 3 resulted in new contributions to the discipline of science and mathematics teacher preparation.

Fourth Major Action: Promising Practices for Science and Mathematics Teacher Preparation

The principal investigators of the TLC undertook a pilot effort in the summer and fall of 2011 to develop an approach to identifying promising practices that could help to define features of quality in science and mathematics teacher preparation. We invited members of The Leadership Collaborative to submit nominations of elements of their programs for consideration as "promising practices". We recognize that there is no commonly accepted definition or agreed-upon set of metrics to apply to the term "promising practice" in teacher preparation. So for our purposes, we operationally defined a promising practice as a unique effort or a notable extension of an existing practice for which data exist to support a positive impact on one or more of the core purposes of SMTI: to increase the quantity, quality and diversity of science and mathematics teachers.

The nominated promising practices were required to directly address one section of the Analytic Framework -- a tool designed to identify policies and practices within institutions that support the recruitment, preparation, induction and development of science and mathematics teachers.

Institutional nomination(s) could be for:

1. An entire science or mathematics teacher preparation program that incorporates one or more of the five Critical Components and Goals of the Analytic Framework (See Coble, 2012a for more details on the Analytic Framework);
2. One of the Analytic Framework Critical Components and one or more of the objectives and strategies under that Component; or
3. Selected Analytic Framework strategies.

Seven institutions of the 25 in the TLC responded to the pilot, several submitting more than one practice, to give us a total of 13 nominations to review. Each of the nominations was critiqued by a panel of three reviewers with extensive knowledge of the research base and practice of science-mathematics teacher preparation. An essential criterion for acceptance as a "promising practice" was submission of evidence supporting the impact on the quantity, quality and/or diversity of teacher candidates.

The review process resulted in designation of five of the 13 submissions as promising practices.

- Colorado Learning Assistant (CO LA) at the University of Colorado Boulder
- Modeling Instruction: Content & Pedagogy at Florida International University
- Science Teacher Induction Network (TIN) at the University of Minnesota
- Scope and Sequence Matrix for the UKanTeach Program Courses at the University of Kansas
- UKanTeach at the University of Kansas

The Learning Assistants Model at the University of Colorado Boulder so impressed the reviewers that they dubbed it an 'exemplary practice'. Although we had no formal criteria, the external reviewers and project staff agreed there was abundant evidence that the CO LA model has transformed undergraduate STEM courses and dramatically increased the interest and engagement of STEM faculty and students in K-12 STEM teaching, and spread the CO LA model effectively across the nation through peer adoption of the model by other institutions.

Through this pilot process, APLU sought to test how to create a potential national network of institutions to implement and assess three transformational strategies:

1. The use of a rigorously developed, evidence-based tool for institutions to systematically *identify* and *document* effective science and mathematics teacher preparation practices;
2. The development of a formal mechanism for the academy to *assess* and *confirm* promising practices in science and mathematics teacher preparation; and
3. The creation of a respected national platform to *share* and *disseminate* promising practices in science and mathematics teacher preparation.

What we learned: The pilot process used to identify promising/exemplary practices in teacher preparation in the United States worked well. Using the Analytic Framework as a tool to elicit applications helped to provide guidance to potential applicants, and a basis for evaluation for reviewers. While fewer than half of the institutions that submitted applications were successful in being designated promising practices, all learned from the process. Most learned that they did not have sufficient data or rigorous analysis to justify claims that the practice was promising. Even some of the successful institutions learned that they needed more coherent structures for providing data about their program practices. Some of the unsuccessful submissions learned that what they felt was unique and promising, was in actuality rather widespread (thus, further validating the need for a national clearinghouse of vetted successful practices in science and mathematics teacher preparation.)

The effort was time-intensive, and would need substantial start-up and sustained financial support if it were to be scaled up. However, for the value that a rigorous and respected review process could make to the science and mathematics teacher preparation community, the investment seems worthy of consideration.

Communications and Dissemination: The promising practices were posted on the SMTI website (http://www.aplu.org/page.aspx?pid=2311). For all the promising practices selected, we provided a concurrent session slot at the SMTI 2012 National Conference, June 6-8, 2012, in Old Town Alexandria, Virginia. Each promising practice was featured:

- *WORKSHOP Introduction to the Colorado Learning Assistant (LA) Program* - Laurie Langdon, University of Colorado Boulder
- *STEM Teacher Preparation; Everythingisconnected* - Steven B. Case, University of Kansas - Presentation (https://www.aplu.org/document.doc?id=3911)
- *Physics Modeling Instruction* – Eric Brewe, Kenneth Furton, and Laird Kramer, Florida International University
- *The Minnesota Teacher Induction Network: Providing Continued Support to Our Teacher Candidates During Their First Year of Teaching* - Gillian Roehrig, University of Minnesota. Presentation (http://www.aplu.org/document.doc?id=3919)

Next Steps: The identification of promising and exemplary practices could be a useful complement to the *Ten Key Questions Universities Leaders Should Ask About Quality Science and Mathematics Teacher Preparation* (see Fifth Major Action). These ten questions have already been mapped to the Analytic Framework (Coble et al., 2012), but what is lacking are examples of how those strategies, and others yet to be identified, are working in practice. Indeed, the application process could also be extended to invite submissions of strategies related to the five core components of teacher preparation contained in the Analytic Framework that have yet to be identified in that work. We believe it would be very helpful to have a database resource of vetted practices that could be accessed by preparation programs from across the country, and even globally.

Fifth Major Action: Seeking Consensus on Essential Attributes of Quality Science and Mathematics Teacher Preparation Programs

When APLU launched SMTI in 2008, it was quickly discovered that campus leaders needed guidance on what actions to take. Finding no comprehensive source to describe effective practices or high-quality programs – ones that produce competent novice teachers – SMTI Co-Director and grant Co-PI, Charles Coble, undertook development of the Analytic Framework (Coble, 2012a; Coble et al., 2012), a catalogue of effective strategies along a continuum from recruitment to preparation to induction support for novice teachers. This work was supported in part by this grant and reported on in earlier annual reports. But as the Analytic Framework grew in complexity, senior leaders from APLU member institutions began to ask, "What are the most critical components or indicators of quality programs?" They wanted to identify the most important levers to push to promote program improvement and quality on their campuses and beyond. We recognized that this question was important not only to APLU's constituency, but to a wider audience with interest in examining the quality of teacher preparation programs.

In order to address this challenge, we embarked upon a different path than the usual reviews of research and reports. We recruited 32 national teacher-preparation experts, practicing teachers, and policy leaders for individual telephone interviews and 45 representatives of six disciplinary and professional societies for group interviews.

Respondents were asked to describe their vision of the key characteristics of an ideal science and mathematics teacher preparation program, and questions about their view of the status of program evaluation, and research evidence for program and teacher quality. Our analysis of the response data identified clear consensus conclusions from these people who are deeply engaged in and knowledgeable about secondary science and mathematics teacher preparation. We defined consensus as near, but not necessarily complete, unanimity. The results were compiled into four thematic briefs that are detailed in full in the report (Presley and Coble, 2012), and are highlighted below. Interviewees and focus-group representatives were invited to Boulder, Colorado, for an intensive one-and-a-half day colloquium to engage in a deeper discussion going beyond the original protocol questions into questions of implementation.

Four Themes Emerging from the Interviews and Focus Groups

Theme #1: Entry and Exit Requirements

Consensus Statement: It matters a great deal who is selected into and who exits from teacher preparation programs, but quality control of who enters and who exits programs is not done well across the country.

- The right conditions and incentives are not in place to recruit consistently strong teacher candidates to prepare for careers in science or mathematics teaching.
- We want candidates who are academically accomplished, passionate about teaching young people, and persistent in achieving their goals.
- Recruitment needs to be much more deliberate, rigorous, and selective for the knowledge, skills, and dispositions associated with good teaching in mathematics and science.
- There should be rigorous standards and performance assessments for all candidates seeking teacher licensure in science and mathematics.

Theme # 2: Clinical Preparation

Consensus Statement: Learning to teach should primarily be a clinical practice thoroughly grounded in the realities of schools and classrooms.

- Well-sequenced and well-supervised clinical experiences should provide teacher candidates with realistic experiences upon which to base their decisions to pursue teaching and, for those that do, to prepare them well for the realities and the possibilities of teaching.
- Teacher candidates should be engaged in and experience the art and craft of teaching early and often.
- Recognized master teachers and teachers-in-residence should play a key role in the clinical preparation of teachers.
- Clinical experiences should be in a range of grades in schools that closely mirror where teacher candidates' ultimate placements will likely be.
- There should be strong support for program completers through their critical induction period into teaching.

Theme #3: Knowing and Teaching Disciplinary Content

Consensus Statement: Teachers need to both know the discipline they are teaching and have the pedagogical skills to teach it, requiring deep collaboration between education and disciplinary departments.

- There is no one best program design. But all programs must be rigorous and accommodate students at different points in their education, their lives, and their financial circumstances.
- Pedagogical content knowledge needs a more prominent place in program design and should be blended into the instruction of content courses.
- Out-of-classroom experiences help teacher candidates gain an understanding of the nature of the discipline beyond what they can acquire in classes.
- Education and disciplinary faculty, along with master teachers and teachers-in-residence, need to create strong partnerships.
- No matter the discipline of training, teachers need to be able to make cross-disciplinary connections in their teaching.

Theme #4: Evaluation and Research to Improve Teacher Preparation

Consensus Statement: There is a need for ongoing evaluation within programs, and better research to inform the design and development of teacher preparation programs.

- Continuous evaluation of every phase of teacher preparation programs, including strength of school partnerships, is essential for their ongoing improvement.
- We need to know much more about what constitutes effective practices both in teacher preparation and in the K-12 classroom, and how to measure them.
- Too few education researchers undertake research that will produce results that are directly applicable to teachers and classrooms, and there are too few doctoral programs that produce the kinds of researchers needed to conduct such research.
- While there is no one best structure for science and mathematics teacher preparation, what is known about attributes of successful program components needs to be communicated faster and more clearly.

Ten Key Questions University Leaders Should Ask

We began this project intent on identifying key attributes of quality teacher preparation programs. In addition to our confirmation of the strong foundation of agreement for action, and the importance of continuous formative evaluation, we were able to draw upon all of the data gathered from interviews, focus groups, and the Boulder Colloquium to craft a list of ten key questions that can guide college and university leaders, and others wanting to gain insight into the quality of teacher preparation programs under their purview. These ten questions were then mapped to the Goals, Objectives, and Strategies of the Analytic Framework (Coble, 2012a). This provides some practical guidance for implementing or improving these program practices. We hope that institutional leaders and others responsible for ensuring that preparation programs produce competent novice teachers will use these questions to guide their quest for quality in their teacher preparation programs. We provide here the ten questions, and refer the reader to Coble (2012b) for implementation strategies.

1. *How do you as a leader convey a clear and strong message for the value of quality teacher preparation at your institution?* What evidence can you present to affirm your commitment?

2. *Does the selection process into teacher preparation programs attract candidates with demonstrated academic success and evidence that they have the skills and dispositions that will likely lead to their becoming good teachers?* What data are available to support the response?

3. Are *there exit standards beyond minimum state requirements that ensure that the teacher education programs produce competent novice teachers?* What, specifically, are the higher exit standards if they exist?

4. *Do teacher preparation programs have a culture of evidence and accountability, one that tracks and assesses the progress of teacher candidates from entry to completion and as novice teachers and uses those data to make appropriate interventions and program changes as warranted?* Is a comprehensive assessment plan in place, are data being collected and is there evidence that the data are being used to counsel students and improve the program?

5. Is *teacher preparation clinically based, all the way from early classroom exposure, to more extensive, but still well supervised student teaching?* Is there a documented sequence of clinical development and evidence of effective monitoring and mentoring by skilled professionals?

6. *Do teacher preparation programs blend courses in disciplinary content and pedagogical content knowledge so that students acquire deep content knowledge and the ability to transmit core disciplinary concepts in an age-appropriate way?* Is there evidence of such content-pedagogical integration and agreement on its effectiveness by disciplinary and pedagogical faculty?

7. *Do programs have vigorous university-school partnerships that demonstrate a shared responsibility for teacher preparation and development with the public schools in which most teacher candidates are placed for clinical experiences and student teaching?* Is their evidence that the partnerships are recognized formally and show evidence of sustainability?

8. *Are master teachers and teachers-in-residence, those with strong disciplinary backgrounds and evidence of exemplary understanding of teaching, engaged as essential colleagues in teacher preparation?* What is the evidence of teacher engagement and the impact of the engagement?

9. *Do the teacher education programs ensure that co-operating classroom teachers assigned to student teachers are master teachers or are teachers under the supervision of a master teacher in the school or district?* What is the evidence that selection, preparation, and compensation of cooperating teachers assure effective development of teacher candidates?

10. *Do the teacher education programs include support to their novice teachers through an induction period as a part of their formal programs?* What specific programs of induction support are in place and what evidence of impact is available?

Conclusion: The consensus statements demonstrate that there is considerable agreement among a broad spectrum of experts across the nation with regard to what it takes to prepare high quality science and mathematics teachers. There is a strong foundation of agreement upon which strategies for action can build. But what was quite different from the current search for post-preparation evidence of teacher quality was a call for continuous quality improvement processes that examine every step along the pipeline of teacher preparation. Evaluation in this context is conceptualized as an ongoing formative process that each and every program should be practicing on a continuous basis. Teacher preparation programs most certainly must be held accountable for the performance of their newly certified teachers, perhaps through a nationally applied approach such as edTPA (AACTE, 2012). But in a continuous improvement model, this is not an after-the-fact judgment of quality, but instead a point along the teacher preparation pathway from recruitment through preparation and into practice.

Furthermore, we found that the Ten Key Questions mapped well to the pre-existing Analytic Framework, which already contains strategies and tactics for implementing them. Our results demonstrate the need for a different vision of how best to move programs towards quality, that of continuous improvement through a demonstrated commitment to self-improvement using specific criteria that have begun to be developed through this project.

Communication and Dissemination: The results of this study have been/will be presented broadly.

- A panel co-chaired by Presley and Coble at the SMTI National Conference in Alexandria, VA, June 2012;
- The SMTI Executive Committee annual meeting in Denver, CO, November 11, 2012;
- A panel co-chaired by Presley and Coble at the upcoming AACTE meeting in Orlando, FL on March 1, 2013. Other panelists will be David Monk, Dean, College of Education, Pennsylvania State University, and Cynthia Bauerle, Senior Program Officer, PreCollege and Undergraduate Science Education, Howard Hughes Medical Institute.

In addition, APLU plans to issue a press release for dissemination to the education media before the end of 2012.

Next Steps: Mapping the Analytic Framework to the Ten Key Questions revealed that all five components and goals of the Analytic Framework are embedded at different places within the Ten Key Questions, as are all 13 of the objectives. In total, 28 of the 56 strategies, or 50%, are directly linked to the Ten Key Questions. However, as users begin to utilize these tools to improve program quality, other strategies will likely be identified or developed – and we encourage users to communicate suggestions for additions or improvements to the Analytic Framework to the author or APLU/SMTI staff. Depending on additional funding, four strands of work are needed to continue this quest for continuous quality improvement in teacher preparation using the knowledge gained in the development of the Analytic Framework (Coble,

2012a; Coble et al., 2012), the four thematic briefs and the Ten Key Questions (Presley and Coble, 2012; Coble, 2012b), which we plan to disseminate widely.

1. Establish a database of science and mathematics teacher education programs built on the expanded use of the Analytic Framework, and analyze the accumulated assessment data to provide a foundation for program improvement.

2. Build a vetted portfolio of exemplary and promising practices that exemplify the goals, objectives and strategies of the Analytic Framework.

3. Seek additional strategies that augment those already identified here as mapping to the *Ten Key Questions.* Since the latter were developed through a process that was independent of the Analytic Framework, it is possible that upon deeper examination, additional approaches either can be identified as currently existing, or will be created to better address these program attributes.

4. Build criteria and metrics for assessing the degree to which the strategies are successfully being implemented within programs. This would help programs as they undertake their individual ongoing assessment for continuous improvement, but might also lead to the development of a national competition to recognize exemplary teacher preparation programs.

V. Communications and Dissemination

In addition to the dissemination activities highlighted in the preceding major actions, we continue to distribute a SMTI Newsletter of STEM education news to more than 1500 subscribers and to update the SMTI website with current STEM education news.

For a full list of publications from this project with URLs, see Attachment 1. Also, we have posted all TLC related publications at http://www.aplu.org/page.aspx?pid=2552.

VI. Research and Evaluation

Teacher Production and Targets

In 2009, we requested that each institution or system provide "the number of students that your institution/system has prepared for initial licensure/certification as Science and Mathematics teachers" for Academic Year X. The Academic Year for 2010 (as an example) is defined as July 2009 – June 2010. We asked for data from AY 2006 onwards. So, we have science and mathematics teacher production from AY2006-AY2011. Note that not all students who are recommended for licensure/certification follow through to become certified, or become teachers. For high school teacher preparation, we asked for the total unduplicated headcount for all STEM fields. We also requested the number recommended in the following disciplines: mathematics, physics, chemistry, physical sciences, biology/life sciences, geology/earth sciences, general science, and other STEM areas of initial licensure/certification not already included. The data does not allow us to determine if the students recommended for certification in a specific discipline have a major in that discipline. We requested no information about the majors of the students recommended for certification. For middle school teacher preparation, we asked for the total unduplicated headcount for all STEM fields and the number recommended in mathematics and in general science. Because some programs have dual certifications,

meaning a student is recommended in more than one disciplinary subject, institutions and systems were allowed to report a single student in more than one disciplinary category, but that student was only counted once in the "Total unduplicated headcount for all STEM fields."

Over the last four years, we have collected teacher production data for the TLC institutions (25) and the broader SMTI effort (132 institutions and 13 systems). Several of the TLC institutions included increasing their teacher production as a goal of their Implementation and Assessment Plans. Here we include data from academic year 2006-2011 for all TLC institutions (Table 2), an analysis of how well they met their growth targets (Table 3), and a comparison of the growth to the larger SMTI effort (Table 4).

Findings:

- There was teacher production growth over the period of the grant, with a total of almost 300 new teachers prepared across The Collaborative from 2008-2011 (Table 2).

Table 2. Science and Mathematics Teacher Certificants from TLC Programs

	AY 2006	AY 2007	AY 2008	AY 2009	AY 2010	AY 2011
Unduplicated Middle and High School Science/Math Certificants	955	870	867	892	1052	1154
Biology/ Life Sciences	194	198	184	176	219	202
Chemistry	90	74	64	83	79	70
Geology/ Earth Sciences	69	46	51	41	68	45
Mathematics*	507	465	468	473	568	663
Other science	24	23	9	7	11	8
Physical Sciences	19	13	17	24	17	17
Physics	40	44	40	44	54	44
Science, general*	196	183	191	220	246	320

*Mathematics and Science, general include middle and high school numbers.
Columns may not add up due to multiple certificants among disciplines.

- The institutions made significant progress on reaching their teacher production growth targets - 92% of their production goals (Table 3).

Table 3. Targets for the TLC

	Actual AY 2009	Actual AY 2011	2011 Targets	Targets for Final Year**	Percent of 2011 Target
Unduplicated Middle and High School Science/Math Certificants	892	1154	1254	1777	92%
Biology/ Life Sciences	176	202	210	305	96%
Chemistry	83	70	69	107	101%
Geology/ Earth Sciences	41	45	49	81	92%
Mathematics*	473	663	712	893	93%
Other science	7	8	11	18	73%
Physical Sciences	24	17	23	45	74%
Physics	44	44	48	82	92%
Science, general*	220	320	387	476	83%

*Mathematics and Science, general include middle and high school numbers.
**Final Year could be 2011-2015

- Overall, the TLC increased their production by 28.6%, while the broader SMTI effort, over the same time period, increased by 9.6% (Table 4)[1].

Table 4. Middle and High School Science and Mathematics Teacher Certificants

	Percent Change (average 2006-2008) compared to 2011	
	TLC	SMTI
Unduplicated High School and Middle School Science and Mathematics Certificants	28.6%	9.6%

Conclusion: TLC institutions have made more progress, overall, in the production of science and mathematics teachers than the control group of SMTI non-TLC institutions. The attention brought to bear on science and mathematics teacher preparation at TLC institutions appears to have helped some institutions further increase their production in a relatively short period of time.

[1] The SMTI comparison data do not include the TLC data.

Testing the Theory of Action

Our theory of action is that institutional change depends both on top leadership commitment and faculty ownership of the actions. APLU brings the first, since it is composed of public research universities whose representatives include presidents and provosts. Collaboration with the American Physical Society was established as a grant partner to spur disciplinary faculty commitment.

WestEd external evaluation of the role of APLU

The extent to which the contribution of APLU has helped to advance STEM teacher preparation at the participating TLC institutions was addressed directly by our external evaluator, WestEd (Britton, 2012). The overarching foci of the grant's external evaluation by WestEd were determining:

(a) any **value-added role by APLU** to the institutions' existing efforts;

(b) whether provosts became engaged and the **effects of provosts' roles**:

(c) any effects of the Analytic Framework (AF) on Members' efforts

In the first three years, WestEd undertook telephone surveys of Team Leaders, and once with Provosts, to investigate the impact of APLU and APS at the institutional level. In the final external evaluation year, WestEd undertook four case studies (California State University Fullerton, South Dakota State University, University of Arkansas, and University of Maryland College Park) to further investigate how APLU's focus on teacher preparation and university leadership involvement had manifested itself at institutions that appeared to be in the process of change. We include here text from the 2012 WestEd evaluation, and use a different type-face to so indicate.

Formative data indicated that, overall, participants valued **all** of the project's core events and activities: annual meetings for team leaders; the one-time meeting for provosts; the project staff's communications and organization; and the Analytical Framework.

Summative data from the Year 3 team leader interviews and site visits to four campuses indicated that:

1. Participants highly valued project meetings.

2. Institutions universally felt that having the imprimatur of APLU catalyzed whatever existing efforts had been underway.

3. For most campuses, use of the Analytical Framework prompted some new ideas about changing STEM teacher preparation, particularly for recruitment (efforts to recruit students into teacher preparation paths/programs).

4. About two-thirds of the institutions had active, unprecedented involvement from provosts, which led to more and/or different than usual efforts.

5. A prevalent change was the ability of provosts to leverage broader participation across colleges and departments, particularly crossing the sometimes challenging boundaries between education colleges/departments and those housing the STEM disciplines.

1. Participants Highly Valued Meetings (PhysTEC, Provost, Regular Annual)

PhysTEC meeting. Prompted in part by the APLU project, 17 of the 25 institutions sent one or more representatives to a PhysTEC meeting in Pittsburg, organized by another project rather than the APLU grant. On a scale of 1 (lowest) to 5 (highest), participants provided high average ratings of most sessions (between 3.8 and 4.5); only one or two participants assigned the lowest ratings of 1 or 2 to any regular session. Participants

particularly valued learning about the Learning Assistants (LA) program, highlighted by the University of Colorado-Boulder, and the UTeach program. In fact, the exposure of these programs at this event spurred many institutions to use/adapt the LA program in their APLU project plans, and accelerated plans by some institutions to explore becoming UTeach replication sites.

Provost meeting. Both provosts and their accompanying APLU-project team leaders highly valued the one-time meeting that APLU designed expressly for provosts. While APLU had solicited attendance by provosts at regular annual projects meetings, almost no provosts had previously elected to come. Given that fact and in light of the broad and extensive responsibilities of provosts at their campuses, it is remarkable that APLU was able to secure attendance for the special meeting by provosts from 60% of the project institutions. All attending provosts and 83% of team leaders completed surveys anonymously after the event. Provosts indicated the following:

> All but two provosts agreed or strongly agreed with the questionnaire statement "the conference was sufficiently valuable to warrant my time."
>
> Over 80% of provosts agreed with the statement "I am more likely to take an active role in effecting institutional changes (in STEM teacher preparation, and/or research about it)."
>
> They particularly valued sessions about leading a process of change, and identifying promising practices for changing the institutional culture about STEM teacher preparation.
>
> All but two provosts agreed with the statement "I gained ideas that I otherwise was unlikely to acquire in the near future for making changes at my institution."

Regular Annual Meetings. Based on annual phone interviews with team leaders from every institution, we report that, without exception, the team leaders generally found the regular project meetings to be useful. Interviewees often related examples of learning new specific ideas, projects or programs from the agenda, or from networking with participants from other institutions.

In addition to benefitting from the agenda and networking opportunities, participants from the same institution felt have having protected time together strongly advanced their local project work, for example[2]:

> "It was very much for our institution a working meeting, where we could take back what we had accomplished at the meeting and begin working towards the implementation of those objectives. We were away from the university, we were away from other items that required our attention, and it was really useful for us. And it's difficult for everyone, I think, to find two or three days in common to dedicate to a project, and we appreciated that."

2. APLU Imprimatur and Activities Provided Added Value to Local Efforts

All but a couple of team leaders reported specific ways that participating in the APLU project brought added value to their local efforts, from modest leveraging/catalyst functions to more extensive and more substantive. In the more conservative cases, having the national spotlight of being part of the APLU project caused presidents or provosts to endorse and give authority to those who were already effecting enhancements in STEM teacher preparation, but they took few additional leadership actions. Nevertheless, having this heightened visibility/status on campus empowered these few individuals to further strengthen their efforts.

> "I've been talking about this and doing it to an extent for years. I could never get the time, the financial resources, the staffing resources to take that idea further. But now, when I walk into [provost office] and say, 'Yeah, now, as part of the APLU thing we're working on', then [provost] sits up and says, 'What do you need?' This would not happen without the APLU relationship."

A great majority of team leaders saw greater institutional benefit (beyond their own efforts) from having the facilitation, catalyst, and imprimatur of the APLU for their local efforts, as illustrated by these statements: "But

[2] Some provosts and their team leaders emphasized the same point about their time together during the special provost meeting, discussed above.

I think that the fact that APLU focused attention on that gave us a point where we kind of focused some of that energy, because you had kind of a program and a process and a commitment, and so I think that opportunity was right for our institution. We had many pieces in place, but the APLU opportunity I think gave us a catalyst to move forward…So, I think it kind of stimulated a renewal of attention." "Part of the magic of this process is that having that an outside partner that's a little bigger, a little more weight and having a bully pulpit, I guess, of change and reform is very helpful to us."

3. Using Comprehensive Analytical Framework Identified Gaps, Connections

The great majority of institutions found it useful to comprehensively map everything relevant to STEM education and teacher preparation, as illustrated below: "I think the articulation by APLU has been helpful. They've articulated [through the Analytical Framework] so many pieces of the pie, and that has put some things on the radar for me to think about and watch for internally that it would have taken me longer to pick up on. It's not that I wouldn't have noticed those things, probably, or worried about them or thought about what we're doing about them. But the occasion about being asked what we're doing about them has prompted me to have more sensitive radar for the range of issues associated with the endeavor."

As illustrated by the following comment, participants at many institutions were surprised to discover that there were existing efforts of which they were unaware:

> "I think what is really working is the attention that the [university administrators] have gotten about what's going on at their own university from the project, and the analytical framework in particular."

Institutions successfully used the AF to identify and prioritize one or more of three kinds of new goals: (1) identifying existing efforts that they wished to strengthen, (2) discovering latent connections between programmatic/project efforts across campus that could be marshaled for a synergy between them; or (3) discovering gaps or under-treated aspects of STEM education and teacher preparation that they wished to begin addressing more earnestly, or for the first time. The most common new pursuit was strengthening recruitment of students into teacher preparation paths or programs.

4. Engaged Provosts Leveraged Noteworthy Changes

At the two-thirds of institutions where provosts or other central campus administrators became more than nominally engaged, team leaders saw this as important and influential for the advancement of the local project's efforts:

> "The first benefit, of course, at the institutional level is that it then brings in the involvement of the provost and president in terms of their awareness, their interest in the SMTI. And because of that level of involvement there's been a pretty wide distribution of support and of information about the program at the institution."

The four WestEd case studies included in this final grant report also provide clear, examples of strong actions by provosts, for example:

- personally co-leading the local project and participating in some meetings;
- fostering recognition of STEM faculty attention to education as being relevant in promotion applications;
- personally enlisting relevant faculty and administrators that had not previously worked together;
- providing team leaders with notable access to them and being responsive to requests; and
- providing high-leverage resources[3] such as providing space, funding outside speakers from another APLU project institution, and protecting critical faculty lines or degree programs in the face of overall cuts due to recent state financial crises.

5. Wider Campus Participation Across Common Institutional Barriers

At some campuses, the APLU project's empowerment was limited mostly to those who already were engaging in advancing STEM teacher preparation. At many other campuses, the project drew in a wider set of players -- sometimes many more: "It's brought together a set of faculty that wouldn't otherwise have got together. We have different projects where we work with physics faculty, or biology faculty, or whatever, and it did create that umbrella to bring all of those

[3] modest but strategic dollars that catalyzed events or actions that were quite influential to the change process

people to the table at the same time. That was useful." "I see more involvement with faculty in liberal arts, in particular with people in the [science] department. They actually have been involved in things which are the first time that I have seen them step up and be actively involved in the project other than just talking about what they already were doing."

It was particularly interesting that the project on many campuses was able to broach the historically common barrier that can exist between faculty in education and the STEM disciplines, as illustrated below:

> "For us, one of the biggest advantages to doing it was it was the first time that it really brought education faculty and science and math faculty in the room together to talk about the program."

6. Appropriate APLU Attention to the External Evaluation

Finally, we note that APLU project staff actively considered the external, formative evaluation data from WestEd, and made project adjustments to ameliorate issues raised by participants or to enhance some project functions.[4]

- Some participants in Year 1 had raised concerns about the project's almost sole focus at the outset on teacher preparation in physics; the APLU staff diversified the project at subsequent events to include additional foci on other sciences and mathematics.
- When Year 1 evaluation data indicated that provosts were not engaging in the project as desired, APLU adjusted the project plan and budget to create a Year 2 meeting expressly for provosts and their accompanying team leaders.
- Project leaders made modest changes in the agenda and facilitation of later meetings to foster more inclusiveness of participants regardless of whether they were based in STEM disciplines or education; this was a response to concerns by the latter in Year 1 that a perception sometimes existed of affording them lesser roles/status in project activities or staff communications.
- As requested by team leaders during evaluation interviews, the APLU staff at some effort created information displays and files that would aid participants from one institution to glean ideas from another.[5] As a second strategy for fostering cross-institution collaboration, the APLU established voluntary working groups on specific topics related to advancing STEM teacher preparation, which had been selected by participants during an annual project meeting. Half of the institutions had a faculty member volunteer to participate in these working groups.

Conclusion: WestEd's external evaluation confirms the findings we reported in First Major Action, and in earlier annual reports, that a national organization, in this case APLU, can influence and guide its member institutions, in this case major research-focused universities, to strengthen their science and mathematics teacher preparation programs.

Team leaders' opinions regarding APLU's helpfulness

In the final year of the grant, APLU administered a survey to Team Leaders to assess both their institutions' progress as well as assess how helpful APLU had been to their efforts (Attachment 3). Reading across all questions for how APLU's activities were helpful, its role in galvanizing university leadership ranked third, with 16 of 23 respondents mentioning this somewhere within their final reports. Furthermore, raising the profile of teacher preparation rated second. This provides additional evidence of APLU's effectiveness in regards to the primary postulate of the project. Table 5 shows other aspects of APLU's efforts that were well regarded by participants, which will be addressed within the analysis of our supporting questions that follows.

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[4] Project staff members' direct interactions with participants also led them to consider these changes. However, project leaders also deliberated over evaluation reports in a way that did result in 'data-driven decision making'.

[5] Surprisingly, later interviews indicated that only two team leaders related making any use of this information after receiving it. For those interviewees offering an explanation, the common view was that while everyone embraces the idea of learning from another institution, they find it hard to consider how to adapt the ideas from another institution's context for their local use.

Table 5. Ways APLU was Helpful	
	Number of Institutions
Organized and supported participants to attend conferences and other cross-institutional efforts that helped create a community of learners	22
Raised the profile of teacher preparation on their campus and/ or nationally	18
Galvanized university leadership	16
Involved the institution, specifically for teacher preparation, in a national movement/APLU initiative that could be leveraged for greater involvement for reforms on campus	13
Required an IAP, annual targets, and reports that helped focus goals	13
Provided an impetus to work on strengthening teacher preparation	6

Supporting research questions

In order to guide our strategies to promote institution change, we early-on identified five supporting research questions that would test whether our plan of action could be related to institutions' change outcomes. We had planned to use data from each year's Implementation and Assessment Plan (IAP) submissions by institutions to track their progress against their self-identified goals and measures of progress. While most institutions did submit an initial IAP and follow-up annual reports, the scope of reporting was so broad, and so imprecise with regard to measures, that it was in most cases not feasible to achieve the assessment of progress we had planned. In prior years, we used open-ended questions that made it difficult to aggregate results across institutions. So in the last year of the grant, we used a different approach. We provided a set of questions to which each Team Leader was asked to respond. Submissions were much more comparable for this final reporting in Year 4. Kacy Redd undertook the data analysis. In this section we provide the five supporting research questions and a summary of the findings.

Data Sources: The survey was designed to elicit information from participants about accomplishments as their final reports (Attachment 3). There were questions in the survey about successful outcomes from institutions' Implementation and Assessment Plans, barriers to change, most helpful activities by APLU, and recommendations to APLU if similar projects are undertaken in the future. Twenty-three of 25 participating institutions provided responses.

Institutional Team Leaders were asked to identify their most important accomplishment, with an option to add another. In addition to their most important accomplishments, institutions reported successful outcomes in questions 3 and 4. Their responses were classified to identify how many institutions reported similar outcomes as their top accomplishments by drawing from their answers to questions 1, 3 and 4 (Redd, 2012). Tabulated results represent a view of priorities at institutions, but do not capture every accomplishment, since we did not ask for an exhaustive

list of accomplishments. These reported successful outcomes were coded as meeting one of three categories of change at the institution:

- Program improvement: affecting a course in a department or implementation of recruitment strategies, like adding a course that provides a "taste of teaching" experience;
- Program restructuring: affecting the structure of a degree-granting program, which might include multiple departments, but is restricted to modification of a program; or
- Campus-wide change: affecting multiple departments and that are second-order changes[6] (Kezar, 2001; Levy and Merry, 1986) that transform the underlying structure, processes, policies, values, or mission of the institution.

Although institutions had change at multiple levels, an institution was categorized based on only one level of change, in the following ascending order: program improvement, program restructuring, or campus-wide. This is because the higher up the organizational ladder the change was situated, the broader its impact institutionally.

Redd looked for common themes or core ideas across the institutions that indicated what APLU activities led to the reported successful outcomes. In addition, she used a database that had been built over the course of the four years of the project that tracked attendance of TLC participants in APLU-organized activities. To measure engagement of faculty, staff, and administrators in project activities, she counted attendance at meetings, webinars, forums, or participation on working groups or committees related to the TLC work over the four years of the project. She estimated the hours required to participate in each event and summed this across institutions. Redd then calculated the total time spent, average time spent by participant, and total number of participants for each institution as well as by whether the institution underwent program improvements, program restructuring, or campus-wide change.

The primary hypothesis that a national higher education association can promote institutional change to strengthen science and mathematics teacher preparation has been answered affirmatively by WestEd's external evaluation through the collection of opinion data over time from Team Leaders and institutions' provosts, as well as four site visits in the last year of the grant. Those case studies, in particular, demonstrate particular aspects of organizational change that could be related to APLU (Britton, 2012). Here we explore the extent to which the data collected over the duration of the project could be correlated with change – that is – could levers be identified that others could use to promote change?

1. *What evidence is there that changes that were implemented strengthened teacher preparation and were institutionalized*?

a) Levels of change:

Nine of the 23 reporting institutions attained change at this highest level (campus-wide), while six restructured their programs, and seven implemented program improvements (Table 6). A couple of institutions increased their influence with state-level agencies as well. One institution reported that it has a representative from their state's Department of Education on their SMTI-TLC committee, and that faculty shared their SMTI-TLC goals and work with this state's Senate

[6] First order changes are small, incremental changes in one domain of the organization that do not change a core aspect of the organization.

and House Education Committees through briefings during annual legislative sessions. One institution that did provide a final report did not indicate any change to its program or campus, and it is designated as "no change". Two institutions that are members of the collaborative did not provide final reports and were coded as "No Report".

Table 6. Level of Change at TLC Institutions

	No Report	No change	Program Improvement	Program Restructured	Campus-wide Change
Number of institutions	2	1	7	6	9

The *campus-wide changes* that occurred at nine institutions consisted of setting STEM teacher preparation as a critical priority of the campus, creating new STEM education centers, or having joint or shared governance of science teacher preparation between the College of Education and College of Arts and Sciences including university-wide councils (Table 7). All but one of these campus-wide changes, which is a university-wide STEM education taskforce, appear to represent an institutionalized or a permanent change to the university.

Table 7. Outcomes and Level of Change

Most Successful Outcomes	Level of Change	Number of Institutions
Creation/ increased support of STEM education center	Campus-wide	4*
Became a UTeach replication site	Campus-wide	2
Campus-wide STEM Education Taskforce	Campus-wide	1
Joint governance of teacher preparation	Campus-wide	1
Institutionalization (and national dissemination) of LAs	Campus-wide	1
University-wide STEM education council for teacher preparation	Campus-wide	1
Became a 4+1 year program	*Program Restructuring*	1
Became a 4 year program	*Program Restructuring*	1
New masters in STEM education	*Program Restructuring*	1
Tracking teachers for continuous improvement	*Program Restructuring*	1
New science and education minor	*Program Restructuring*	1
New 4 year degree for secondary teachers in science disciplines	*Program Restructuring*	1
New recruitment strategy	Program Improvement	4
Increased teacher enrollment/ production	Program Improvement	2
Increased external funding (NSF grant)	Program Improvement	1

*One institution started a STEM education center and became a UTeach site and is double counted

Two institutions referred explicitly to an increase in institutional commitment. At one institution, participation in the TLC "drove STEM education, including teacher preparation, to the forefront of the institution's mission and precipitated a sustained commitment to STEM education." This university is breaking ground on a new STEM education center. Another Team Leader reported that their institution "experienced a transformation of culture around STEM teacher preparation"

even in the face of changes in leadership at the provost's and deans' positions "reflecting an institutional level of commitment to change."

Not all efforts were university-wide. Five institutions made changes to their *program structure*, becoming a 4-year +1 year master's program; shortening to a 4-year program; adding a science education minor; adding a masters' programs in science education; and/or requiring a major in the discipline instead of in education. These examples of program restructuring represent permanent changes. The sixth institution that was categorized as undergoing program restructuring has started tracking new teachers to determine their patterns of employment and to engage in continuous improvement of their teacher preparation program.

Seven institutions reported *program improvements*. These were often new recruitment strategies, like implementing the Learning Assistants model (Otero et al., 2006; Otero, Pollock, and Finkelstein, 2010), which recruits strong undergraduate science students as peer mentors and provides them with an integrated pedagogy course. One institution did not implement strategies or programs during this grant period that can be attributed to the TLC. This institution had significant leadership changes and cited turnover in leadership as a barrier to reform.

b) Promoting strategic thinking:

Four final reports indicated that APLU encouraged more strategic thinking for sustainable institutional change. As one respondent wrote:

> "Also at the early APLU project meeting, participants developed a greater appreciation for the spotlight and opportunity that the APLU publicity afforded institutions, but also the resulting increased responsibility to fulfill the project's charge. These realizations motivated our team members to consider ambitious changes that would be most consistent with the nature of the APLU project, i.e., ones that are systemic and at the institutional level…While the campus may have proceeded at some point to do something like **[removed to de-identify]**, there is a general sense that the APLU project can be credited with ensuring that it happened now, moved quickly, and with a more ambitious design than likely would have happened in the absence of the APLU spotlight, opportunity, and support."

Conclusion**:** These reported outcomes provide evidence that nearly all institutional participants implemented changes that strengthened teacher preparation and were institutionalized.

2. Does the composition of teams, drawing from both Colleges of Education and Colleges of Arts and Sciences, impact change?

a) Cross-college collaborations

One strategy that APLU used with the TLC was to encourage collaborations between faculty from colleges of education and colleges and arts and sciences based on the proposition that alignment and coherence of the content knowledge taught in science courses and the pedagogical knowledge and training traditionally provided in education courses is critical for well-prepared science teachers. Science faculty can also model good science teaching for prospective K-12 science teachers. Thus, more successful teacher preparation reforms will occur if faculties from both fields are involved in improving science teacher preparation.

To investigate whether the project was able to engage faculty from colleges of education and colleges of arts and sciences, the number of participants from each institution who were in science or mathematics disciplinary fields, education, or administration was calculated using the participant data base that had been built over the four years of the project. Across all 25 institutions and 185 participants, the project engaged more education faculty (45% of participants) but science faculty were well represented (38%); the remaining participants were university administrators (18%). Although this does not provide definitive evidence that having faculty from both colleges involved in the TLC efforts was necessary for improved teacher preparation, the most cited positive outcome attributed to the TLC was strengthened cross-college collaborations. As one faculty member from a college of education wrote, "The TLC served as a powerful incentive for recruiting new members to the institutional planning team."

One of the requirements of the TLC was creation of an institutional team, and more than half of the institutions with program improvements identified this as being beneficial:

> "The advent of the TLC led to a team, which until that point had not existed. Communication and planning among members of the team has led to understandings and advances that have been very beneficial for the University."

> "Many meetings and work sessions took place that served to bring together a number of schools and departments on campus that do not usually meet, do not usually have chances to unite around a common goal, and do not usually have an idea of how their work impacts another unite [sic] on campus. The results of these meetings and working sessions have generated program changes, opened doors for collaborative extramural grant submissions, and generated the groundwork for possibly establishing a STEM center on campus."

Fewer institutions that had campus-wide changes wrote about the TLC catalyzing the relationships that helped bring about transformation, which suggests that the ingredients necessary for reforms were already established at those institutions that had campus-wide change.

b) Level of engagement by the participants

To probe the connection between level of engagement with APLU and level of change, the time spent by members of institutions on APLU activities as well as the total number of participants involved from each institution was analyzed.

The more people who were involved in their TLC efforts, the more likely it was that campus-wide change occurred (Table 8). However, there does not appear to be a relationship between time spent by each participant and level of change. One possible interpretation for more participants being associated with campus-wide change is that institutions poised for campus-wide change saw the value of being involved with a national higher education association and had the resources and relationships in place to maximize the leveraging potential of APLU to further their on-campus goals. Another could be that by bringing together a larger group of invested individuals, the institution was able to take on institution-wide change. Furthermore, we show later that almost two-thirds of those with campus-wide change identified galvanized university leadership as a most helpful aspect of APLU's actions. The prominence of this campus leadership voice may have signaled a positive culture for participation.

Table 8. Participant Participation					
	Level of Change				
	No report	No change	Program-improvement	Program-restructuring	Campus-wide
Number of participants per institution					
Total # participants	14.0	3.0	44.0	37.0	87.0
Mean # of participants	7.0	3.0	6.3	6.2	9.7
Median # of participants	7.0	3.0	4.0	5.0	9.0
Minimum # participants	7.0	3.0	2.0	2.0	2.0
Maximum # participants	7.0	3.0	11.0	14.0	15.0
Time spent (hours) per institution per participant					
Mean time	47.9	79.5	51.6	45.3	44.6
Median time	48.0	51.0	48.0	36.0	27.0
Minimum time	2.0	48.0	1.5	2.0	2.0
Maximum time	102.0	139.5	143.0	130.0	192.5
Number of institutions	2	1	7	6	9

Conclusion: Broader participation matters for campus-wide change, not the time spent collaboratively.

3. Does participation in a project that includes a number of major public universities promote institutional change?

a) Community of learners

Each year APLU organized opportunities for TLC members to meet and share their strategies and practices with a purpose of building a community of learners, most often done during a one-day meeting that preceded the SMTI National Conference. There was also a three-day Leadership Retreat for TLC Team Leaders and provosts to discuss common challenges and successful strategies for improving teacher preparation, with a focus on institutional change and the role of leadership (Frank and Shapiro, 2010a). In year three of the grant, the project PIs supported three learning communities, each with representatives from eight institutions. These meetings and projects allowed faculty members from across institutions to interact and work together on common goals.

Nearly all respondents referred to this ability to meet colleagues and to learn from one another as being helpful (see Table 5). And 12/23 respondents identified these activities as among the two most important things APLU did to aid campus activities – particularly for those with program-improvement and program-restructuring levels of change (5/7 and 4/6) (Table 9). One commenter wrote, “The annual TLC meetings provided a vehicle to learn about best practices occurring at other institutions and a forum to discuss options for replicating some of those models (e.g., Learning Assistant Program)….” Another member valued the SMTI national meetings and learning communities because it “allowed us to share our accomplishments in

growing our teacher preparation programs and also to seek solutions to shared challenges such as changing the culture around tenure and promotion policies and procedures."

Table 9. Most and Second Most Helpful Thing APLU Did to Aid Campus Activities

	Highest Level of Change		
	Program-improvement	Program-restructuring	Campus-wide
Number of Institutions	**7**	**6**	**9**
Organized conferences/support community of learners	5	4	3
Raised the profile of teacher preparation on campus and/or nationally	4	3	5
Galvanized university leadership	0	0	5

b) Raising the status of teacher preparation institutionally and externally

Explicit in APLU's involvement in teacher preparation was the proposition that a national association could help promote the critical need for improved teacher preparation in research-focused universities. Institutions reported that APLU's promotion of teacher preparation was impactful, and respondents overwhelmingly cited the importance of APLU in increasing the status of teacher preparation (see Table 5). The TLC provided additional "validation" and "justification" for participation in the work of improving teacher preparation and "contributed to the overall status of STEM teacher education."

The advocacy of APLU was important not only at the local level on campuses but also at the national level. Some institutions were able to capitalize on being part of a larger national network to acquire external funding and partners and to sustain their programs from campus budget cuts. A few institutions indicated the value of having their programs or practices reach a national audience.

Conclusion: Participation in a project that includes a number of major public universities did promote institutional change, but the intervening role of a national association was evident, both directly, and through the increased attention from senior leadership. The national voice gave legitimacy to an increasing focus on science and mathematics teacher preparation at these institutions. Those campuses that reported program improvements or program restructuring were most likely to identify the usefulness of conferences and a community of learners, while raising the profile of teacher preparation locally or nationally held some prominence for all groups.

4. *Does the intensity of senior institutional involvement impact institutional change?*

a) Impact of university leadership

A primary strategy of the TLC was to leverage APLU's influence with presidents, provosts, and other university leaders to promote the importance of teacher preparation, to inform them of model practices for teacher preparation, and to engage them in the work of the TLC when possible. In this section we draw from responses to all questions to comprehensively assess whether APLU was able to galvanize university leadership for improvement of teacher preparation at their institutions. Many Team Leaders commented on this aspect of participating in the grant:

> "The most important thing was providing our provost with the knowledge of how important this issue is nationally, and information that allowed her to speak to the issue and the needs of the campus and the state. She is very busy, and it was by your empowering her that she was able to take a leadership role. There are simply too many things she must attend to for her to develop expertise in each area. Her being able to serve as a leader had an impact on the breadth of interest we have from STEM faculty currently."

> "SMTI provided a pathway for administrators to participate in the education transformation process on campus, allowed them to achieve a broader perspective of the national education landscape, learn about the reform practices in place in other institutions, and establish the institutions prominence on a national level. Through engaging with other SMTI institutions and learning about their approaches, they deepened their understanding and were more able to engage other faculty and administrators inside the institution as well as those external to the institution. They build stronger collaborations with faculty and, together, could speak with one coherent voice. This emboldened them to embrace opportunities to change institution practices to support faculty and students."

> "APLU/SMTI has provided a context for talking with campus leaders that they can relate to. Receiving communications from APLU regarding SMTI and attending SMTI sessions at APLU conferences helped to keep the priority on their radar in a straightforward manner; rather than faculty members having to do the selling based on their involvement in the field, SMTI was able to raise the issues on our behalf."

A few respondents referred to the Leadership Retreat with their provost as being especially helpful. As one Team Leader wrote:

> "A major turning point for **[university]** was our provost's attendance at the SMTI meeting in Miami. She had heard first-hand about all the exciting things going on at other universities, which strengthened her resolve to ensure that we would make progress at **[university]**."

b) University leadership and level of change

At the beginning of this project, we postulated that the level of engagement of university leadership would impact the level of change possible on a campus. Having APLU galvanize university leadership, most often their provost, was most highly valued by institutions that had campus-wide change (5/9, Table 9). Indeed, those with this level of change were the only ones choosing this aspect of APLU leadership as most or second-most important. This provides strong evidence of the importance of visible university leadership to promote campus-wide change.

However, Team Leaders noted ways in which APLU's activities were helpful across several other questions in the survey. Reading across all questions for how APLU's activities were helpful, we found that respondents from institutions that had campus-wide changes or restructured their programs were more likely to report that their university leadership was involved or supportive of their change efforts; all but one respondent in each category referred to the engagement of university leaders (Table 10). In contrast, for those institutions that implemented program improvements only, the majority (4/7) did not make reference to their university leadership being involved. It does appear that university leadership is important for reforms that are at the campus- or program-redesign levels.

Table 10. Ways APLU was Helpful

	No change	Program-improvement	Program-restructuring	Campus-wide
Number of institutions	**1**	**7**	**6**	**9**
Organized and supported participants to attend conferences and other cross-institutional efforts that helped create a community of learners	1	7	6	8
Raised the profile of teacher preparation on their campus and/ or nationally	0	5	5	8
Galvanized university leadership	0	3	5	8
Involved the institution, specifically for teacher preparation, in a national movement/APLU initiative that could be leveraged for greater involvement for reforms on campus	0	5	3	5
Required an IAP, annual targets, and reports that helped focus goals	1	3	3	6
Provided an impetus to work on strengthening teacher preparation	0	4	3	2

c) Impact of leadership turnover

Each institution was asked if there had been a change in leadership for the Team Leader, key deans, provost, or president during the TLC (Table 11). One-third of the institutions in the TLC had a Team Leader change, and 18/23 had a change in at least one key dean. Furthermore, half had a change in the key provostial position, and 9/23 (39%) had a change in institutional leader. Only two institutions had no change.

Table 11. Turnover in Leadership Over the Four-Year Project

	Number of institutions
Change in Team Leader	8*
Change in key Dean	18
Change in Provost	12
Change in President/Chancellor	9

*One institution did not answer this question, but did have a change in Team Leader. This institution is included in this count.

The responses to the question of the impact of leadership turnover on campus activities (Q5) were incomplete and difficult to interpret. In addition to the four respondents who reported a negative impact of leadership change (Table 12), participant behaviors indicate the potential negative impact of leadership turnover. Originally, the TLC had 27 institutions. Two institutions dropped out of the TLC early on after changes in leadership or substantial restructuring of programs. Another institution had a change in the Team Leader in 2011 who was also their provost. Since the turnover in leadership, this institution has not been as involved and did not submit a final report. For those who provided a final report, five respondents with significant changes in leadership including the Team Leader, chose not to answer this question. (We were aware of changes from the project database that has been maintained, and other sources.) Coupled with the four respondents who indicated a negative impact, we interpret these responses or lack of responses to indicate a possible negative impact of changes in leadership for 12 of the original 27 institutions. Thus almost half of the institutions that experienced changed leadership found that it impeded their participation in the TLC, while the other half indicated that changes in leadership were either positive (6), neutral (4) with changes not slowing forward momentum, or mixed with both positive and negative aspects (2). Some wrote that turnovers allowed them to reassess their goals and commitment to STEM teacher preparation and to hire supportive leadership. Only two institutions did not have a change in leadership at the Team Leader, dean, provost or president level.

Table 12. Perceived Impact on Campus Efforts of Leadership Change

	Number of Institutions
Yes and the changes were **positive**	6
Yes and the changes were **neutral**	4
Yes and the changes were **negative**	4
Yes and the changes were **mixed (both positive and negative)**	2
No changes in leadership	2
No answer given by the respondent	5
No report	1
Dropped out of the TLC early	2
Dropped out of the TLC late	1

The data on level of engagement by institutional participants also suggests that changes in Team Leaders can impact progress on reform efforts. When the top ten institutions were ranked based on total amount of time spent involved with TLC efforts as measured by attendance at APLU events, three were institutions with program improvements (not campus-wide change or program restructuring) (Table 13). These Team Leaders and their teams were attending meetings and participating in working groups. However, each of these institutions had a Team Leader change, which seems to have slowed their progress in accomplishing wider reform.

Table 13. Team Leader Change for Top Ten Institutions with Total Time Engaged in TLC			
	Level of Change	Team Leader Change	Total time spent by Institution (hours)
Institution A	Program-restructure	No change	686
Institution B	Campus-wide	No change	579
Institution C	Campus-wide	No change	546
Institution D	Program-improvement	Yes, leader change	522
Institution E	Campus-wide	No change	510
Institution F	Campus-wide	No change	504
Institution G	Program-improvement	Yes, leader change	499
Institution H	Program-improvement	Yes, leader change	480
Institution I	Campus-wide	No change	472
Institution J	Campus-wide	No change	428

Conclusion: While most participants valued the heightened involvement of their senior leadership through the galvanizing action of APLU, its impact was most clearly felt by those institutions that achieved campus-wide change. Furthermore, team-leader change slowed institutional progress during this project.

5. Do institutions find comprehensive, multi-college planning through a common project tool to be useful, and do institutions use it to effect changes?

As one of the first tasks in the MSP RETA project, we requested that each institution complete an Implementation and Assessment Plan (IAP). The purpose of the IAP was to choose the key activities the institution would undertake as part of the TLC, identify strategies to reach these goals, and choose measures that could be used to monitor progress. A third of the respondents (8) indicated that creating this IAP was useful, with one Team Leader commenting, "Writing the IAP was a very worthwhile exercise – it brought people together for a common conversation, and there is something about forcing us to commit on paper that made it more real and strengthened resolve to follow through." Another important component of the IAP was a request for measurable targets that could be assessed at the end of the grant period. About a quarter of final-year IAP respondents (5) indicated that having to set these targets aided work on campus and helped them make progress on their goals. As one TLC Team Leader wrote, "The annual reports and the requests for data were strategies which kept our "feet to the fire." We had to publicly track and monitor our progress (or, lack thereof)." Another respondent answered, "…annual report submissions put the spotlight on the importance of attending to STEM education issues and served as the impetus for pursuing systemic changes that would be both sustainable and impactful."

Conclusion: It had been the intention of the project leaders that institutions use the Analytic Framework simply as a framework from which to select one or two critical actions for program improvement upon which to focus during the project. Most participants took a more comprehensive approach, and this seems to have been most useful to institutions that were less poised for campus-wide change. The flexibility that we gave participants over the course of the project, however, did provide the opportunity for some to take advantage of the planning tool.

VII. Summary of Key Findings and Conclusions

APLU's theory of action was substantiated

Over the course of the four years of this project, we have been able to demonstrate that a national organization can influence institutional change to strengthen science and mathematics teacher preparation at large public research focused universities. The results show that institutional leaders will engage when

- The work is part of a national effort of similar institutions addressing a critical national issue
- Provided opportunities to gather together along with their own team leaders, and at other meetings to learn and share
- Involved in the process on their campuses

While most participants valued the heightened involvement of their senior leadership through the galvanizing action of APLU, its impact was most clearly felt by those institutions that achieved campus-wide change. Furthermore, team-leader change slowed institutional progress during this project.

APLU's project design helped create opportunities for collaboration and institutional change. These included

- Institutional Implementation and Assessment Plans (IAPs)
- Annual face-to-face national gatherings
- Cross-college teams within institutions that fostered collaboration
- Opportunities for team leaders to generate their own communities of study and action, which produced significant collaborative work

WestEd Evaluation Results (Britton, 2012). Formative data indicated that, overall, participants valued **all** of the project's core events and activities: annual meetings for team leaders; the one-time meeting for provosts; the project staff's communications and organization; and the Analytic Framework.
Summative data from the Year 3 team leader interviews and site visits to four campuses indicated that:

1. Participants highly valued project meetings.
2. Institutions universally felt that having the imprimatur of APLU enhanced whatever existing efforts had been underway.
3. For most campuses, use of the Analytic Framework prompted some new ideas about changing STEM teacher preparation, particularly for recruitment into teacher preparation paths/programs.
4. About two-thirds of the institutions had active, unprecedented involvement from provosts, which led to more and/or different than usual efforts.
5. A prevalent change was the ability of provosts to leverage broader participation across colleges and departments, particularly crossing the sometimes challenging boundaries between education colleges/departments and those housing the STEM disciplines.

Conclusion: WestEd's external evaluation demonstrates that a national organization, in this case APLU, can influence and guide its member institutions, in this case major research-

focused universities, to strengthen their science and mathematics teacher preparation programs.

The level of institutional change accomplished by institutions is related to galvanized university leadership

Nine of 23 participating institutions that provided final reports accomplished campus-wide changes (Redd, 2012). These included setting STEM teacher preparation as a critical priority of the campus, creating new STEM education centers, or having joint or shared governance of science teacher preparation between the College of Education and College of Arts and Sciences, including university-wide councils. Eight of these nine institutions identified APLU's success in galvanizing university leadership as among the helpful things the Association did – and five of them raised this strategy to the most helpful category. Institutions achieving campus-wide change also valued other APLU efforts highly, including the required annual progress report on their Implementation and Assessment Plans, the creation of communities of learners, and raising the profile of teacher preparation.

While the six institutions that accomplished program restructuring also valued APLU's effort to galvanize university leadership, none raised this to the most helpful category. And among the seven institutions that accomplished program improvement as their highest level of change, only three cited galvanization of university faculty as a helpful factor. They were more likely to value being part of a national movement and having an external impetus to work on strengthening teacher preparation.

Conclusion. Visible university leadership is needed to promote campus-wide change.

Strategies for collaborative institutional action

A research effort undertaken by eight participating institutions focused on assessing what was working at institutions with successful reform efforts. Collaboration was identified as essential to success, and five strategies emerged across the institutions for successful postsecondary education collaborations (Bouwma-Gearhart, Perry, and Presley, 2012).

1. Successful collaborations recognize that those involved in postsecondary improvement activities are at different points in their appreciation of interdisciplinary work and the value of others' expertise.
2. Successful collaborations occur when participants recognize that faculty and instructors are likely to be on numerous paths and at different points in their careers with respect to pedagogical issues and experience with education reform.
3. Successful collaborations recognize the critical role of literacy brokers of education research and theory in the collaboration.
4. Successful brokers frame education research and theory in relation to typical STEM research and teaching practices and acknowledged expertise.
5. Formal interdisciplinary collaborative faculty groups help catalyze institutional change.

Conclusion: In order to best drive widespread change and improve postsecondary education, it is critical to identify and empower individuals who can act as brokers between seemingly disparate disciplines in terms of research, theory, and practices and norms, and who can do so in ways that support and capitalize on the diverse experiences and expertise each individual brings to the table.

The study also investigated institutional conditions that promoted successful collaboration and reform (Bouwma-Gearhart, 2012). These are

1. Structural supports including external supports, providing convening space, and utilizing teaching tools in ways that conserve time.
2. Policies and practices that attend to issues of hiring, promotion and tenure. Unique hiring practices and positions held great promise. Many spoke with enthusiasm about the prospect of a new generation of faculty who is gaining a much deeper understanding of STEM pedagogy in undergraduate and graduate school as a result of their involvement in education reform and the opportunity to learn from teaching experts.
3. Fostering STEM faculty participation and interdisciplinary collaboration. Extrinsic factors are important in motivating additional STEM faculty and instructor participation. These include the influence of strong department chairs and deans and other respected STEM colleagues, financial motivation, affiliations with prestigious grants and disciplinary organizations, and the prestige and safety often secured via an already-established and distinguished reform group.

   Four stages of evolution through which STEM faculty progress as they gain understanding and appreciation for education research and theory, and their Education unit colleagues, were identified. These were initial suspicion, followed by awareness and respect for other types of knowledge, then acknowledgement of the values of others' research, and finally, the acceptance of education research as an area of expertise, and its researchers as experts.
4. The need for common focus. STEM reform collaborations are best built around specific foci. Strategies to support the selected focus included the use of data, building synergy with related reform initiatives, and using education theory and research to inform the selected effort.
5. Re-envisioning power towards change. Both explicit, or positional power, and "hidden" power were documented as important for change. Those who made the reform efforts really take hold usually held less traditional positions, especially those in novel faculty positions, and Education faculty with strong STEM training. Even postdoctoral fellows and Learning Assistants had collective power to promote reform efforts. Influential and esteemed faculty were also influential. Most influential were those whose disciplinary education, research and theory expertise and communication skills rose to the level of "literacy broker". These individuals could translate education, research and theory into a form that was understandable and usable by STEM faculty and instructors, and speak the language of STEM with respect to disciplinary ways of knowing and processes.

Conclusion: The approaches detailed in this report provide new insights and confirm others about how to promote institutional change to foster undergraduate education (and by proxy teacher preparation) reform through faculty participation. Many are low cost solutions, and all represent pragmatic practices that provide existence proof that reform is well under way among faculty in research-focused universities, and is becoming integrated into their professional cultures.

Tools to identify and cultivate quality in science and mathematics teacher preparation

The Analytic Framework. This tool, designed for supporting innovation and quality design in the preparation and development of science and mathematics teachers, was refined with support from this project (Coble, 2012a; Coble et al., 2012). It was also used directly as institutions developed their IAPs, and in the design of two additional tools – the Promising Practices Pilot and the initiative to Seek Consensus on the Essential Attributes of Quality Mathematics and Science Teacher Preparation Programs.

Seeking Consensus on the Essential Attributes of Quality Mathematics and Science Teacher Preparation Programs. As APLU institutional leaders became familiar with The Analytic Framework, they began to ask "What are the most important levers to push to promote program improvement and quality" on their campuses. In order to address this challenge, a national study was undertaken that included interviews with 32 national teacher-preparation experts, practicing teachers, and policy leaders, and 45 representatives of six disciplinary and professional societies (Presley and Coble, 2012). Four themes emerged: Entry and Exit Requirements; Clinical Preparation, Knowing and Teaching Disciplinary Content, and Evaluation and Research to Improve Teacher Preparation. Each became a brief that summarizes the substance of the interview process, including consensus statements. After further discussion that brought some of the interviewees together in Boulder, Colorado, in April 2012, a set of Ten Key Questions that university leaders should ask was developed. Each question calls for evidence to substantiate the answers. The questions were also mapped to the Analytic Framework to provide concrete implementation strategies (Coble, 2012b).

The consensus statements demonstrate that there is considerable agreement among a broad spectrum of experts across the nation with regard to what it takes to prepare high quality teachers. There is a strong foundation of agreement upon which strategies for action can build. But what was quite different from the current search for post-preparation evidence of teacher quality was a call for continuous quality improvement processes that examine every step along the pipeline of teacher preparation. Evaluation in this context is conceptualized as an ongoing formative process that each and every program should be practicing on a continuous basis. Teacher preparation programs most certainly must be held accountable for the performance of their newly certified teachers, perhaps through a nationally applied approach such as edTPA (AACTE, 2012). But in a continuous improvement model, this is not an after-the-fact judgment of quality, but instead a point along the teacher preparation pathway from recruitment through preparation and into practice.

The Promising Practices Pilot. Participating institutions were invited to submit nominations for elements of their programs for consideration as promising practices. Using the Analytic Framework as a tool to elicit applications helped to provide guidance to potential applicants, and a basis for evaluation for reviewers. While fewer than half of the institutions that submitted applications were successful in being designated promising practices, all learned from the process. Most learned that they did not have sufficient data or rigorous analysis to justify claims that the practice was promising. Even some of the successful institutions learned that they needed more coherent structures for providing data about their program practices. Some of the unsuccessful submissions learned that what they felt was unique and promising, was in actuality rather widespread (thus, further validating the need for a national clearinghouse of vetted successful practices in science and mathematics teacher preparation.)

The effort was time-intensive, and would need substantial start-up and sustained financial support if it were to be scaled up. However, for the value that a rigorous and respected review

process could make to the science and mathematics teacher preparation community, the investment seems worthy of consideration.

Next Steps: The identification of promising and exemplary practices could be a useful complement to the *Ten Key Questions Universities Leaders Should Ask About Quality Science and Mathematics Teacher Preparation*. These ten questions have already been mapped to the Analytic Framework, but what is lacking are examples of how those strategies, and others yet to be identified, are working in practice. Indeed, the application process could also be extended to invite submissions of strategies related to the five core components of teacher preparation contained in the Analytic Framework that have yet to be identified in that work. We believe it would be very helpful to have a database resource of vetted practices that could be accessed by preparation programs from across the country, and even globally.

Criteria and metrics for assessing the degree to which the strategies are successfully being implemented within programs also need to be built. This would help programs as they undertake their individual ongoing assessments for continuous improvement, but also might lead to the development of a national competition to recognize exemplary teacher preparation programs.

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Attachment 1
Grant Publications/Products

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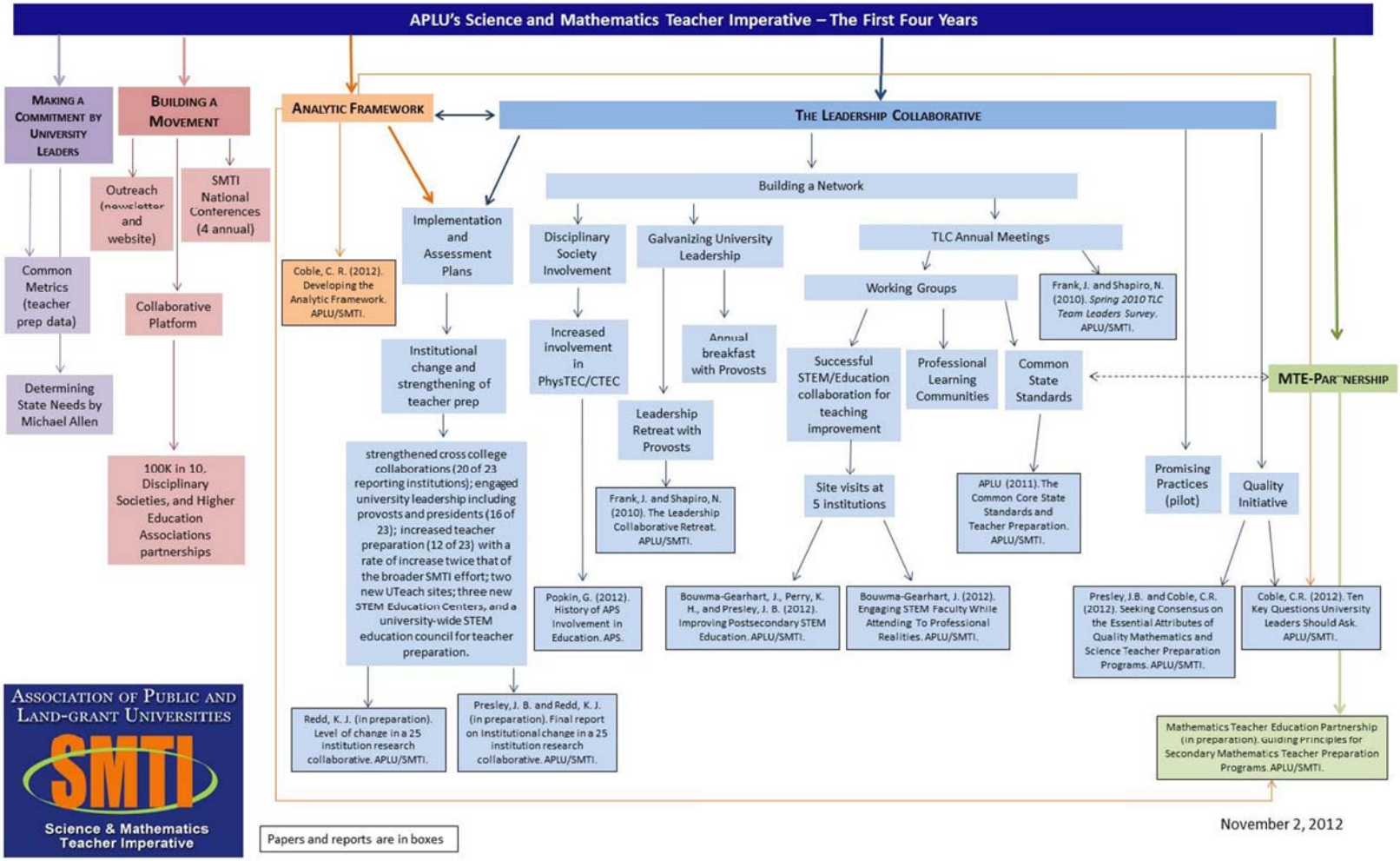
Attachment 2



Attachment 3

Year Four Survey Questions for Team Leader Final Reporting

1. Reflect on the IAP that your team submitted to TLC.
    a. What is the most important success that has been accomplished from your IAP?
    b. What were the conditions that led to this success?
    c. What barriers if any continue to limit ongoing improvement?
    d. Describe how this success led to a permanent change at your institution.
    e. OPTIONAL: Is there a second success that you wish to tell us about? If so, please respond by answering a-d again.

2. Describe <u>one</u> major goal in your IAP that is unfulfilled. What do you think has been the major barrier/challenge to success? *Please limit your answer to one major goal.*
    a. OPTIONAL: Are there any other important goals that went unfulfilled that you want to tell us about? If so, please limit your response to one additional page.

3. What evidence do you have that your science (and mathematics) teacher preparation program(s) has been strengthened by your institution's participation in the TLC?

4. What have you, your team, and your institution gained by being a member of the TLC?
    a. You as team leader
    b. Your planning/implementation team
    c. Your institution

5. What leadership changes have occurred during the time of your institution's participation in the TLC?
    a. Team Leader (give dates, positions and names of change)
    b. Key deans (give dates, positions and names)
    c. Provost (give dates and names)
    d. President/Chancellor (give dates and names)
    e. Please describe how any of these changes have impacted STEM teacher preparation on your campus generally and your TLC progress in particular.

6. What was the most helpful thing that APLU did in aiding your work to strengthen STEM teacher preparation on your campus?

7. What was the second most helpful thing that APLU did in aiding your work to strengthen STEM teacher preparation on your campus?

8. Is there something different or more that APLU could have done to support your work to strengthen STEM teacher preparation on your campus?

9. OPTIONAL. Please provide any additional information that you would like to share with us concerning the impact of this A-P-L-U effort on STEM teacher preparation on your campus. *We would appreciate you keeping your response as brief as possible.*