Association of Public and Land-grant Universities

The Science & Mathematics Teacher Imperative

The Leadership Collaborative Retreat

January 6-8, 2010, Coral Gables, Florida

Jennifer Frank and Nancy Shapiro, University System of Maryland

Executive Summary

The Association of Public and Land-grant Universities (APLU)—the nation's public research universities—launched the Science and Mathematics Teacher Imperative (SMTI), to transform middle and high school science, technology, engineering and mathematics (STEM) education by preparing a new generation of world-class science and mathematics teachers. SMTI participating institutions are committed to substantially increasing the number and diversity of high quality middle and high school STEM teachers, identifying immediate and long-term needs for STEM teachers in their states, and building partnerships among stakeholders to address teacher needs on a sustained basis. Currently, 124 APLU institutions are members of the SMTI initiative, including 12 university systems, making it the largest STEM new teacher initiative in the country.

As a subset of SMTI, The Leadership Collaborative (TLC) is a network of 26 institutions that are focusing on institutional change efforts that support the strengthening of teacher preparation programs in the sciences. This project is funded as a Research, Evaluation, and Technical Assistance (RETA) grant under the National Science Foundation's Math and Science Partnership (MSP) program.

APLU held a retreat for members of The Leadership Collaborative in Coral Gables, Florida on January 6-8, 2010. The purpose of the retreat was to provide a forum for TLC leaders to meet face-to-face, to identify common challenges around STEM teacher preparation, and to share successful strategies, with a particular focus on institutional leadership and change. TLC institutions were asked to send their provost and institutional team leader. The retreat had 57 participants, including 24 team leaders and 15 provosts. The agenda encompassed a range of topics, including:

- plenary sessions on the national STEM teacher education challenge, leading change in higher education, and faculty roles and responsibilities
- breakout sessions on science teacher preparation program components, including recruitment, non-traditional pathways, streamlined programs, and mentoring/induction
- role-alike discussions for provosts and team leaders
- other breakout discussions, including:
  - estimating the need for teachers
  - institutional change strategies
  - faculty rewards systems
  - program infrastructure and resources (e.g., funding, campus space)
  - education research in the STEM disciplines
  - reform in STEM undergraduate education, including the use of Learning Assistants
  - TLC resources such as the Analytic Framework
  - supporting programs such as PTEC and PhysTEC

During the TLC retreat, participants and speakers discussed strategies for implementing institutional change and made recommendations to APLU about what the organization should be doing to strengthen science teacher preparation. We provide the major recommendations and strategies in this Executive Summary.

Leading Change in Higher Education

Ann Austin, Michigan State University, provided key questions guiding organizational change in higher education (page 11):

- Is the vision/goal for the change clear?
- Are there multiple opportunities for sense-making about the change?
- Are multiple change levers being used to foster the change process? These levers include vision/mission, structures, processes, infrastructure, human resources/people, culture, and constituencies and partners.
- Are multiple levels of the institution considered in encouraging the change process?
- Is there attention to monitoring and adjusting the change process?

Ellen Chaffee, Association of Governing Boards, discussed the Eight Steps for Successful Large Scale Change (Kotter and Cohen, 2002) and added actions based on her experience as a strategy consultant and university president (page 12):

1. Increase urgency (stay positive).
   Show the need for change—tangible evidence from outside.
2. Build the guiding team.
   Identify, engage, and support the right people.
3. Get the vision right.
4. Communicate for buy-in.
   Keep communication simple and heartfelt, listen, and repeat the message.
5. Empower action.
6. Create short-term wins.
7. Don't let up.
   Use new situations opportunistically to create fresh energy; celebrate; strengthen relationships.
8. Make changes stick.
   Incorporate change into new employee orientation and promote people who embrace the new culture.

Having multiple champions in strategic positions on campus is of critical importance (page 19).

Key Breakout Discussions

Participants discussed several topics during breakout sessions leading to the following strategies and recommendations:

Faculty roles and rewards

Several TLC institutions are examining their existing faculty appointment, promotion, and tenure policies. During a plenary session, Ann Austin outlined six strategies for implementing appropriate faculty rewards (page 14):

- Conduct a thorough review of the institution's tenure and promotion guidelines.
- Ensure that senior academic leaders clearly and consistently articulate faculty roles and priorities.
- Create ample opportunities for faculty networking and cross-disciplinary work (e.g., fellowships, joint appointments, and informal opportunities to make scholarly connections).
- Provide faculty who are engaged in this work with recognition and prestige.
- Explicitly support those faculty who are already committed to the institution's teaching and learning agenda (recognizing that faculty have different pressure points at different stages in their careers).
- Connect interested faculty with interested graduate students.

The discussion sparked by Austin's presentation was continued during a breakout session where participants suggested additional strategies:

- Confront the conflicting message about pressure for research productivity and increased emphasis on undergraduate education and public outreach (page 19).
- Expand professional opportunities for non-tenure-track faculty and try to achieve a "critical mass" of these types of faculty positions in disciplinary departments (page 19).
- Expand appointments and roles for discipline-based education researchers to introduce culture change in disciplinary departments (page 19).

Building institutional infrastructure and sustaining support (page 20)

STEM Centers, units on campus with the primary mission of promoting STEM education, are potential "silo-busters" when they

- Provide a common ground for focusing institutional efforts on STEM education.
- Provide a shared ownership for the institution's STEM agenda.
- Facilitate new pathways for internal and external collaborations.
- Create incentives and efficiencies for involvement by faculty, students, and administrators.

Transforming STEM undergraduate teaching and learning (page 21)

Introductory STEM courses can have a strong influence on student major and career choices, and focused institutional efforts could yield a substantial pay-off in the recruitment and retention of STEM majors and teacher candidates. Participants suggested:

- Improve the environment for undergraduate teaching and learning in STEM disciplines to attract more STEM majors and to increase the pool of potential K-12 teachers.
- Combat the negative attitudes that often steer interested students away from K-12 teaching.
- Actively cultivate student interest in teaching through co-curricular opportunities such as early field experiences in education, volunteer activities in K-12 classrooms, peer tutoring at either the college or K-12 level, and involvement in undergraduate teaching assistant programs.

Promising teacher preparation practices and program strategies (page 22)

- Find effective ways to incentivize STEM majors to consider teaching.
- Increase internal and external marketing efforts by forging ties with university press offices, using social media outlets, and student testimonials.
- Create formal links to community colleges for recruitment.
- Provide STEM majors with early teaching experiences for recruitment and preparation.
- Partner with K-12, and get information directly into the hands of classroom teachers and principals.
- Connect new teachers with scientists for retention.
- Bring STEM teachers (especially novice teachers) together as part of a larger community.
- Provide more flexible delivery formats for professional development.

Cross-Cutting Issues and Themes

Engaging institutional leaders (page 24)

- Increase the level of involvement in and ownership for STEM teacher preparation on the part of presidents, provosts, and other senior higher education leaders.
- Strengthen the policy focus of SMTI—including institutional, state, and federal policies—to encourage more involvement by university leaders.
- Provide opportunities for senior leaders to convene with their peers around these issues.

Unique contribution of APLU institutions (page 24)

APLU institutions prepare thousands of STEM teacher candidates every year, enroll more STEM students than any other type of higher education institution in the United States, and generally have large colleges/schools of education. APLU institutions also do much of the faculty scholarship associated with teacher preparation and the discipline-based education research on STEM teaching and learning.

Linking STEM teaching, learning, and teacher preparation to the core mission of the university (page 25)

- Make clear the connections between STEM teacher preparation efforts and broader STEM undergraduate education reforms—for example increasing the pipeline of STEM majors.
- Create boundary-spanning faculty positions.
- Have STEM centers that facilitate cross-campus

collaboration and have the primary mission of promoting STEM education.

Need for innovation (page 25)

The traditional university "cohort" education model for preparing STEM teachers (in which classes are offered at set times, and sometimes only once per year) warrants attention, particularly for non-traditional students such as working adults and career changers.

Recommendations for APLU

Continue to frame and communicate the key goals and messages of this agenda (page 26).

- Create a unified vision at both the institutional and national level.
- Communicate policy positions.
- Serve as a national platform for advocating for federal and state support of STEM teacher preparation programs in higher education.
- However, be cautious about solely promoting one kind of model at the expense of encouraging innovative new preparation models and new scholarship in the field.

Continue to build collaborations and make connections both inside and outside of this initiative (page 26).

- Provide opportunities for interaction between provosts and STEM teacher preparation program directors and faculty.
- Legitimize the work of STEM teacher preparation and help raise its visibility both at the national and institutional level.
- Build upon existing collaborations (American Physical Society and American Chemical Society), including other higher education associations, disciplinary associations, national initiatives, national partners, funding sources, and Congress.

Continue to facilitate the exchange of information that is occurring around strengthening institutional capacity for and commitment to STEM teacher preparation (page 27).

- Create a clearinghouse for evidence-based best practices at APLU institutions.
- Collect data on institutional policies, practices, and decisions that have helped move the dial on STEM teacher preparation at APLU institutions, including resource allocations, campus infrastructures, tenure and promotion policies, and faculty appointments and staffing models.
- Identify and engage the experts that are part of this initiative.

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ACKNOWLEDGMENTS

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Purpose and Organization of the Report

The Association of Public and Land-grant Universities (APLU)—the nation's public research universities—launched the Science and Mathematics Teacher Imperative (SMTI), to transform middle and high school science, technology, engineering and mathematics (STEM) education by preparing a new generation of world-class science and mathematics teachers. SMTI participating institutions are committed to substantially increasing the number and diversity of high quality middle and high school STEM teachers, identifying immediate and long-term needs for STEM teachers in their states, and building partnerships among key stakeholders to address teacher needs on a sustained basis. Currently, 124 APLU institutions are members of the SMTI initiative, including 12 university systems, making it the largest STEM new teacher initiative in the country.

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Objectives of the TLC

- Create and support a national leadership network of presidents, chancellors, provosts, and their designees who are active at their institutions in improving mathematics and science education and especially teacher education.
- Increase the number of disciplinary faculty who are contributing towards teacher preparation and who assume increased responsibility for mentoring and induction of beginning teachers and the professional development of career teachers.
- Address and make demonstrable progress toward overcoming the challenges that impede the ability of universities to strengthen their mathematics and science teacher preparation programs.
- Widely disseminate the results and lessons learned from this and other related projects.
- Facilitate communication across national networks of mathematics and science education programs.

APLU held a retreat for members of The Leadership Collaborative in Coral Gables, Florida on January 6-8, 2010. The purpose of the retreat was to provide a forum for TLC leaders to meet face-to-face, to identify common challenges around STEM teacher preparation, and to share successful strategies, with a particular focus on institutional leadership and change. TLC institutions were asked to send their provost and institutional team leader The retreat had 57 participants, including 24 team leaders and 15 provosts. The agenda encompassed a range of topics, including:

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This report summarizes the knowledge and findings that were shared during the TLC retreat. It draws upon an analysis of session transcripts, meeting notes, and presenter materials. It is not intended to serve as a chronological proceedings document or an encyclopedic conference report. Rather, its purpose is to provide an analysis of key learnings from presenters and participants, filtered through the analytic lenses of institutional leadership and change. This report begins with a brief overview of the plenary sessions that set the stage for the retreat, including the national context for STEM teacher preparation, leading change in higher education, and faculty roles and responsibilities, including rewards and organizational arrangements. It continues with a synthesis of key breakout discussions related to institutional challenges, strategies, and promising practices in STEM teacher preparation. It concludes with a summary of cross-cutting issues and themes that emerged from the retreat and a recommendations of next steps for the initiative.

National Context for STEM Teacher Preparation

On the same day that the TLC retreat began (January 6, 2010), a letter signed by the presidents of the SMTI institutions was presented to President Barack Obama. These universities pledged to "substantially increase the number and diversity of high-quality science and mathematics teachers we prepare, and to build better partnerships among universities, community colleges, school systems, state governments, business and other stakeholders." Among these institutions, 39 universities and three university systems had also pledged to at least double the number of mathematics and science teachers graduated by the year 2015. The letter was hand-delivered to The White House by Lee T. Todd, Jr., President of the University of Kentucky and Chair of the SMTI Executive Committee; Bernadette Gray-Little, Chancellor of the University of Kansas; William "Brit" Kirwan, Chancellor of the University System of Maryland; Philip P. DiStefano, Chancellor of the University of Colorado at Boulder; Peter McPherson, President of APLU; and **Howard Gobstein, Vice President of APLU and Co-Director of SMTI**. The letter further stated that "we are committed to addressing this critical national need for more and better science and mathematics teachers. Through SMTI we have come together to learn from leading innovative programs, define and assess the quality of our efforts, understand how to better partner with school systems, and challenge ourselves to improve relentlessly our activities."

Building on the synergy and momentum of The White House event during the opening session of the TLC retreat, **Charles Coble, Co-Director of SMTI**, highlighted the role of SMTI as a national initiative and its vision of positioning universities to respond to needs in their states, to have STEM faculty take ownership for K-12 teacher preparation along with their colleagues in education, and to provide robust educational experiences that effectively prepare STEM teacher candidates for their roles in the classroom. He also

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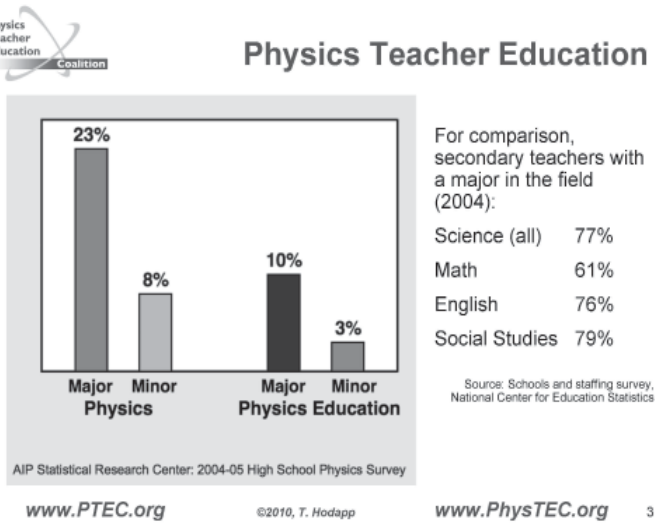
Letter to the White House signed by 79 APLU Presidents and Chancellors

provided an overview of the SMTI goals. In summarizing SMTI's five-pronged strategy, Dr. Coble explained that APLU's efforts were focused on galvanizing higher education leadership, determining needs for secondary mathematics and science teachers, facilitating state fiscal and policy support, helping institutions learn from each other, and teaming with regional and national partners.

As a subset of SMTI, the 26 TLC institutions are particularly well-positioned to provide a network for learning about the factors and conditions that facilitate increased commitment to STEM teacher preparation, as well as necessary changes in culture, infrastructure, rewards, policies, and resources that most effectively promote such commitment. This includes the important role that institutional leaders play in valuing and prioritizing K-12 teacher preparation and work with K-12 schools, and the way these messages are communicated to faculty, students, administrators, and external constituents.

In further placing the impact of STEM teacher shortages into context, **Ted Hodapp, Director of Education and Diversity, American Physical Society**, shared data and observations about the acute national demand for secondary teachers in physics and the physical sciences. Currently, less than one-third of all high school physics teachers hold a degree in physics. While the overall number of graduates with a bachelor's degree in a STEM field has continued to rise steadily over the past several decades in the U.S., this has not been the case in physics, which has experienced a relatively flat trajectory for undergraduate degree production. In fact, when examining the educational pipeline before students even enter higher education, one can see that less than one-third of all high school students take physics. Physics is not even offered as an option in many high schools around the nation, particularly in high-needs schools. And then, among students who graduate from high school and go on to enroll in a college or university, the introductory course in physics is a known barrier to student progression in the major. (At the same time, however, successful student completion of courses in physics, chemistry, and mathematics are positive predictors for bachelor's degree attainment.)



Dr. Hodapp addressed several challenges associated with getting physics majors interested in teaching as a possible career (physics majors are highly sought after and tend to have a variety of opportunities upon graduation), as well as challenges with garnering departmental support for physics teacher candidates (e.g., cultural issues including biases against K-12 teaching as a legitimate career option, institutional expenses associated with preparing physics teachers). He stressed the importance of institutions having a "champion" to serve as an advocate for teacher preparation in the physics department—a faculty member, education researcher, or professional staff member dedicated to thinking about these issues. This is why national initiatives such as the Physics Teacher Education Coalition (PTEC)—a network of 176 institutions committed to developing and promoting excellence in physics and physical science teacher preparation—are so important in creating a more positive climate and institutional conditions for prospective teachers. For example, the 12 universities that have served as PhysTEC sites (and additional institutions

that will be named as PhysTEC grant recipients this summer) are engaged in the creation and demonstration of successful models to increase the number of highly qualified high school physics teachers, to improve the quality of K-8 physical science teacher education, to spread best practices throughout the teacher preparation community, and to transform physics departments to engage more fully in these endeavors.

Also during the opening session of the retreat, **Kevin Foster, Assistant Professor, University of Texas at Austin and AAAS Executive Branch Policy Fellow, National Science Foundation**, communicated NSF's ongoing support of institutional commitment to STEM teacher preparation. Using the example of NSF's Math and Science Partnerships (MSP), he discussed several of the challenges that are associated with STEM faculty engagement in teacher preparation and K-12 partnerships, including long-standing cultural norms in higher education and institutional rewards structures. At the same time, the MSP key feature of "institutional change and sustainability" challenges institutions to "redirect resources and design and implement new policies and practices to result in well-documented, inclusive, and coordinated institutional change." Higher education core partners in MSPs are encouraged to find ways to reward STEM faculty for strengthening their own teaching practices and working with P-20 STEM education initiatives, including teacher preparation and professional development.

In addition, Dr. Foster stressed the importance of creating new models that integrate teaching, scholarship, and service, and that begin to break down some of the traditional silos in higher education that have historically defined faculty work. In this expanded context, service to K-12 schools can be seen as a form of intellectual engagement that can lead to significant scholarly activity. When these activities are relegated to institutional outreach, as is often the case, they can become significantly marginalized. He shared that some institutions are actively pursuing policy changes to support such integration of faculty work, including the University System of Georgia's "Faculty Work in the Schools" Board of Regents policy, approved in 2006.

The University System of Georgia's "Faculty Work in the Schools" Policy is designed to build a system-wide rewards structure that encourages faculty members to sustain their involvement in improving STEM teaching and learning in K-12 schools. This policy originated from Georgia's Partnership for Reform in Science and Mathematics (PRISM), one of the first MSP projects funded by NSF, and represents both a top-down and bottom-up approach to change in higher education—using high-level policy levers to influence changes in culture and practice at the institution and department levels.

This policy had an impact on Georgia State University's tenure criteria. Definition of research now includes:

- "The research program for Science Education faculty is defined as being in **science education and/or lab research**...
- Publications for Science Education faculty may be in either science journals appropriate to the field or in **education journals appropriate to science education**....
- For Science Education faculty, sources of extramural grants may include the US Department of Education, the Georgia Board of Regents, and the Georgia Department of Education."

Leading Change in Higher Education

In the second general session, **Noah Finkelstein, Associate Professor, Department of Physics, University of Colorado at Boulder**, shared a synthesis of research on studying change in STEM higher education, including an interdisciplinary literature review of change strategies conducted with colleagues Charles Henderson and Andrea Beach from Western Michigan University. This review included approximately 400 articles published between 1995 and 2008, including articles written by disciplinary science education researchers, faculty development researchers, and higher education researchers. Based on a citation analysis of the articles in the data set, they found very little interaction between these three groups of researchers, and even minimal interaction within groups. Some of the key findings from this review were that these STEM education research efforts were happening in isolated communities, that they tended to have little or no connection to prior literature, and that they were rarely empirical or experimental in design. In addition, the authors of these articles often assumed that change strategies were successful, even though evidence was weak or anecdotal, and that if change strategies did not produce sufficient evidence of success, it was because more time would be required for change to occur.

In their study, Dr. Finkelstein and colleagues developed a meta-level categorization scheme along the following strategic dimensions. First, what does the change effort intend to directly impact: individuals or environments and structures? Second, to what extent is the outcome prescribed in advance? Is the final state known at the beginning of the process (prescribed) or is it developed as part of the process (emergent)? Along these dimensions, four key categories of change strategies in STEM education emerged from the review of literature:

<table>
<tr><td colspan="4">Individuals</td></tr>
<tr><td rowspan="2">Prescribed Final Condition</td><td>Tell/teach individuals about new teaching conceptions and/or practices (e.g., dissemination (SER, FDR), focused conceptual change (FDR)).</td><td>Encourage individuals to develop new teaching conceptions/practices (e.g., reflective practice (FDR), action research (FDR), curriculum development (SER)).</td><td rowspan="2">Emergent Final Condition</td></tr>
<tr><td>Develop new environmental features that require/encourage new teaching conceptions and/or practices (e.g., policy change (HER), strategic planning (HER)).</td><td>Empower collective development of environmental features that support new teaching conceptions/practices (e.g., institutional transformation (HER), learning organizations (HER)).</td></tr>
<tr><td colspan="4">Environments/Structures</td></tr>
</table>

C. Henderson, N. Finkelstein, & A. Beach (to appear). "Beyond Dissemination in College Science Teaching: An Introduction to Four Core Change Strategies." Journal of College Science Teaching. v39 n5 p18-25 May 2010.

SER=disciplinary science education researchers

FDR=faculty development researchers

HER=higher education researchers

Following Dr. Finkelstein's presentation, **John Frederick, Provost, University of Texas at San Antonio**, moderated a panel discussion on "Leading Change in Higher Education," which provided a variety of perspectives on the change process from the angles of theory and research (Ann Austin), organizational strategy (Ellen Chaffee), practice (Nancy Shapiro), and leadership (Shirley Strum Kenny).

Ann Austin, Professor of Higher Education at Michigan State University, opened the session with a discussion about leading organizational change in higher education, with a particular emphasis on lessons learned from research. In looking at institutional change efforts, it is important that they take into account the institution's culture, history, mission, values, and multiple goals, as well as acknowledge that universities are loosely-coupled systems with multiple authority and power structures. Thus, effective organizational change strategies must view higher education institutions through multiple frames (e.g., political, structural, symbolic), work with various system elements within the institution (levers), and involve all levels of the institution (university-level, college-level, department-level, and faculty-level). Dr. Austin discussed seven distinct levers for institutional change in more detail—vision/mission, structures, processes, infrastructure, human resources/people, culture, and constituencies/partners. She then described processes of organizational change including mobilization (providing vision, providing professional development, creating enthusiasm), implementation (ensuring the appropriate structures and processes are in place, including financial, human, technical, and reward systems), and finally, institutionalization (measuring progress, ensuring accountability, and ensuring ongoing funding and support). She concluded with a series of key questions guiding organizational change in higher education:

Institutional change efforts should consider the institution's culture, history, mission, values, and multiple goals as well as acknowledge that universities are loosely-coupled systems with multiple authority and power structures.

- Is the vision/goal for the change clear?
- Are there multiple opportunities for sense-making about the change?
- Are multiple change levers being used to foster the change process?
- Are multiple levels of the institution considered in encouraging the change process?
- Is there attention to monitoring and adjusting the change process?

Levers for Institutional Change

1. Vision/Mission
2. Structures
3. Processes
4. Infrastructure
5. Human Resources/ People
6. Culture
7. Constituencies and Partners

Ellen Chaffee, Association of Governing Boards (AGB) Senior Fellow, examined the notion of "strategic change" as institutions move from the status quo (characterized by security and expertise), to a transition phase (characterized by disruption and turmoil), to a new state that can be scary and vague for the organization. In terms of implementing successful change, she illustrated a model for the change cycle (pressure for change, clear shared vision, capacity for change, actionable first steps, model the way, reinforce and solidify change, and evaluate and improve) and discussed the consequences of missing a step in the change cycle, which can lead to quick starts that fizzle, false starts, or longer-term efforts that still do not end up sticking. She addressed the importance of institutional leaders building a guiding team, setting the right vision, communicating for buy-in, empowering action, creating short-term wins, and making change stick. From a systems theory perspective, she also spoke about the importance of aligning the various systems of an organization—interpretive (symbolic), adaptive (biological), and linear (mechanical)—so that successful change can occur. Here the change management concept of the "North Star" was first introduced—what is the unifying vision for these efforts, and what results or outcomes will make all of these efforts worthwhile? Simultaneously, what "ship" will guide organizational members in that direction? What resources are already available, and what additional resources will be needed (e.g., time, money, expertise) on this journey?

Eight Steps for Successful Large Scale Change

1. Increase urgency (stay positive)
   a. Show them the need for change – tangible, evidence from outside
   b. Successful change requires about 25% of employees be convinced that change is necessary –now
2. Build the guiding team
   a. Proactively identify and support people and initiatives that are already on the right track
   b. Engage the right people; solicit and support their ideas for key elements and change process
   c. Model the trust and teamwork needed; widen the network; welcome/engage new members
   d. Structure meetings to minimize frustration and increase trust
   e. Confront any instances of undermining or slowed momentum; seek to entice but do not add support for anyone who needs to be "on the bus" but is not
3. Get the vision right
   a. Try to literally see possible futures
   b. Emotionally moving visions so clear they can take just one minute or one page
   c. Bold strategies for bold visions
4. Communicate for buy-in
   a. Keep communication simple and heartfelt; listen
   b. Understand what people are feeling before you communicate; speak to anxieties, confusion, anger, and distrust; use metaphors and analogies
   c. Repeat, repeat, repeat the message
5. Empower action
   a. Remove as many obstacles as possible
   b. Find and share "We won, you can, too" anecdotes
   c. Pursue recognition and reward systems that inspire, promote optimism, build self-confidence
   d. Do not launch 50 projects at once or stretch the truth
6. Create short-term wins
   a. Most people need short-term proof that their efforts are leading somewhere
   b. Make wins as visible as possible to as many people as possible
7. Don't let up
   a. Complacency and exhaustion can set in mid-process – people need rejuvenation
   b. Aggressively eliminate work that can disappear now
   c. Use new situations opportunistically to create fresh energy; celebrate; strengthen relationships
8. Make changes stick
   a. In a change effort, culture comes last, not first
   b. Incorporate change into new employee orientation
   c. Promote people who act according to the new way
   d. Tell vivid stories over and over

Almost always, the core method is "see, feel, change," not "analyze, think, change."

Eight Steps: Kotter and Cohen, The Heart of Change, Harvard Business School Press, 2002. Sub-points: Academy for Leadership and Development, Ellen Chaffee, Ph.D.

Nancy Shapiro, Associate Vice Chancellor for Academic Affairs at the University System of Maryland, shared results from an NSF Knowledge Management Dissemination project called Change and Sustainability in Higher Education (CASHÉ), a study that documented evidence of curriculum transformation, faculty engagement, and sustainable change among higher education institutions involved in MSP projects. She shared categories of findings along the following seven dimensions: institutional culture/context, role of MSP project leaders, impact of institutional leadership/support, investment/motivation of participating faculty, structural changes, course/curricular changes, and project sustainability. Among the most relevant lessons learned from this study was that leadership matters—the critical roles that provosts, deans, and department chairs play in recognizing and rewarding faculty, as well as their top-down advocacy and support for bottom-up faculty leadership in STEM reform. The CASHÉ study also elicited examples of how institutions are transforming to meet the challenges of this work, including boundary-spanning positions (e.g., joint appointments), new roles for non-tenure-track faculty and instructional staff, and the creation of new structures such as multidisciplinary STEM centers and K-12 partnership outreach units. Other findings from the study that were relevant to TLC included links between faculty work with K-12 schools (including teacher preparation) and the reform of STEM undergraduate education—which often came as a "by-product" or unintended consequence of the partnership work. At the same time, challenges remained for the MSP projects as they sought to link this work more closely to the core educational mission of their institutions and create legitimate avenues for faculty research and scholarship from such engagement, versus their efforts being regarded solely as outreach or service.

A relevant lesson from CASHÉ was that leadership matters. Provosts, deans and department chairs play a critical role in recognizing and rewarding faculty, as well as supporting and advocating for bottom-up faculty leadership in STEM reform.

Shirley Strum Kenny shared her leadership experiences on organizational change in higher education as **President of Stony Brook University for 15 years**. While Stony Brook originated as a teachers' college in 1957, its mission abruptly shifted during its first year following Sputnik and the subsequent launch of the Space Race. Since it largely developed as a research institution from that point and the undergraduate educational programs were built downward, it was a challenge for the institution in the 1990s, when accreditation bodies increasingly asserted that the institution needed to pay more attention to undergraduate education. The leadership question, then, was how to change the culture to focus on something that was not a top priority for the institution historically. Dr. Kenny spoke about the importance of engaging the faculty leadership directly in these developments and intentionally creating structures through which these conversations and initiatives could unfold. In terms of the preparation of future K-12 teachers, Stony Brook's School of Education was dismantled in the 1970s, and teacher preparation programs have been run out of individual academic departments ever since. As a result, future teachers, including those in STEM, are closely embedded within the discipline department structure and are heavily encouraged to conduct research as undergraduates—future STEM teachers are considered as scientists. Coming full circle with her remarks, Dr. Kenny concluded with the observation that the National Defense Education Act was a compelling call to action for the nation in 1958, and likewise APLU and other policy groups need to communicate in similar language that not only mobilizes the federal government to provide financial and policy support for STEM, but that simultaneously rallies university leaders, faculty, and students around STEM teacher preparation and STEM education as important institutional priorities.

A challenge for institutional leaders is how to change the culture to focus on something that is not a top priority for the institution historically.

Faculty Roles and Responsibilities

Rita Cheng, Provost of the University of Wisconsin-Milwaukee, moderated a general session on "Faculty Roles and Responsibilities," which provided a variety of institutional perspectives on faculty rewards and organizational arrangements for the administration of STEM teacher preparation programs at TLC institutions.

Ann Austin, Professor of Higher Education of Michigan State University, led off with a presentation titled "Prospects for Changing the Culture for Faculty Rewards." She discussed both extrinsic faculty rewards such as tenure, promotion, and time release, as well as intrinsic faculty rewards such as recognition and prestige, collegial relationships, intellectual stimulation, and professional autonomy. While these factors can serve as positive motivators for change, there are other factors that create resistance for change within the traditional parameters of university rewards systems, including the fact that faculty are simultaneously situated in multiple cultures (i.e., the academic discipline, the department, and the institution); that they have multiple and often competing demands and time commitments; and that they are socialized through the graduate school process to value research and funding as the premiere professional rewards structure. While there may be deep-seated resistance to change within the culture of higher education, Dr. Austin pointed out several encouraging developments, including the fact that many faculty are already interested in and looking for institutional support to focus on teaching and education reform. Likewise, the future faculty pipeline holds promise, as there are increasing numbers of graduate students who are explicit in their focus and commitment to teaching and learning in the discipline.

Ultimately, it is faculty members themselves who control the rewards system, which can serve as both a lever and barrier to systemic change. For institutions that are planning to look at their faculty rewards system as part of a broader commitment to enhancing teaching and learning, Dr. Austin suggested the following strategies:

- conducting a thorough review of the institution's tenure and promotion guidelines
- ensuring that senior academic leaders clearly and consistently articulate faculty roles and priorities
- creating ample opportunities for faculty networking and cross-disciplinary work (e.g., fellowships, joint appointments, and informal opportunities to make scholarly connections)
- providing faculty who are engaged in this work with recognition and prestige
- explicitly supporting those faculty who are already committed to the institution's teaching and learning agenda (recognizing that faculty have different pressure points at different stages in their careers)
- connecting interested faculty with interested graduate students

Following Dr. Austin's presentation, **Risa Palm, Senior Vice President and Provost, Georgia State University**, provided an institutional view of faculty roles and responsibilities as a member of the University System of Georgia, which adopted a formal policy on faculty

"Work in the Schools" in 2006:

> *USG institutions that prepare teachers will support and reward all faculty who participate significantly in approved teacher preparation efforts and in school improvement through decisions in promotion and tenure, pre-tenure and post-tenure review, annual review and merit pay, workload, recognition, allocation of resources, and other rewards.*

The central question that Dr. Palm's presentation examined is whether a system-level policy mandating academic recognition of work in the schools could be effectively implemented in a research university setting. She provided several examples of ways in which the policy has had a significant impact on faculty work at Georgia State—how it has been embraced by the College of Education, how it has resulted in changes in tenure and promotion criteria in the College of Arts and Sciences, and how it is being carried out in one of the most research-oriented departments (neuroscience) in the College of Arts and Sciences.

As an outgrowth of this policy, for example, Georgia State's College of Education has developed "Cross-Career Learning Communities" involving beginning teachers, student teachers, university faculty, school site coordinators, and experienced teacher mentors, which have resulted in significantly higher retention rates for participating new teachers versus non-participating new teachers. Another direct impact has been in the numbers of university faculty going into K-12 schools to deliver instruction to current teachers, including coursework in reading and language arts, cultural and linguistic diversity, and classroom management. College of Education faculty have also been focused on achieving a greater degree of research integration, using their experiences in the schools as a basis for research and publications in areas such as teacher education, professional development, retention, and placement in high needs schools.

While one would perhaps expect such changes in a College of Education, Dr. Palm also cited several examples of changes within Georgia State's College of Arts and Sciences, including changes in tenure criteria in the College of Arts and Sciences. For example, the scope of research for science education faculty is now defined as being in "science education and/or lab research," their publications may now be in "science journals appropriate to the field" or in "science education journals appropriate to science education," and their external funding sources have now been broadened to include education-oriented agencies such the U.S. Department of Education, the Georgia Board of Regents, and the Georgia Department of Education. In addition to these policy changes in the College of Arts and Sciences, Dr. Palm cited faculty work in one department in particular—the Department of Neuroscience—that directly exemplifies the significant level of faculty engagement that the "Work in the Schools" policy was meant to encourage and reward. Several faculty members in this department are deeply engaged in activities such as standards-based professional development workshops for K-12 teachers, a summer "Brain Camp" for students in grades five through eight, an "Institute of Neuroscience" for high school students, an annual "Brain Bee" for high school students, and a two-day public "Brain Expo" held at Zoo Atlanta each spring.

Dr. Cheng moderated a panel discussion highlighting faculty appointment arrangements for STEM teacher preparation at four different institutions. The discussants were **Keith Sheppard (Stony Brook University, SUNY); Donna Wiseman (University of Maryland, College Park); Valerie Otero (University of Colorado at Boulder); and**

John Yopp (University of Kentucky). These four faculty appointment arrangements are briefly summarized in the following tables:

Stony Brook University, SUNY Model: No College/School of Education Stony Brook's College of Education was eliminated in the 1970s. Since that time, faculty members in the discipline departments have been directly responsible for teacher candidate preparation. This is an arrangement that has worked well for the institution, as future teacher candidates are fully embedded in the academic disciplines and departments, and have comparable opportunities for research, mentorship, and advising as their fellow majors. Mathematics and science educators are appointed to and tenured in their home discipline departments. Non-education discipline faculty have been supportive of these arrangements in their departments, and the institution's teacher preparation program enrollments have continued to rise.	**University of Colorado at Boulder** Model: Discipline-Based Education Researcher Appointments A science educator in the School of Education and a discipline-based education researcher in the Department of Physics, both tenured faculty members, work as partners and counterparts in research collaboration, grant funding, and cross-campus initiatives such as the institution's STEM Learning Assistants program. This model highlights the success of having faculty appointments in strategic places that can have a broader impact for STEM education across the institution, as well as the importance of intentionally creating structural supports and community for faculty in these positions through having a counterpart arrangement between academic departments.
University of Maryland, College Park Model: Joint Appointments Maryland currently has one joint faculty appointment between the Department of Physics and College of Education (a 51% to 49% split), and is exploring the possibility of additional joint appointments. The faculty member in this current joint position has been instrumental in focusing the institution on teaching and learning in the content area and integrating teacher preparation and the undergraduate major more closely, as well as in encouraging and mentoring STEM undergraduate and graduate students who have an interest in the scholarship of teaching and learning. At the same time, this type of arrangement does place substantial demands on the appointed individual(s) to successfully balance and negotiate the politics, culture, and processes of two very different departments.	**University of Kentucky** Model: Campus STEM Center Kentucky's Partnership Institute for Mathematics and Science Education Reform (PIMSER) was an outgrowth of the university's AMSP grant from NSF, and was designed to sustain and expand the institution's partnership and outreach work with K-12 as a cross-campus effort after the grant ended. Full and associate professors are appointed as outreach professors (.5 FTE appointments in PIMSER and .5 FTE appointments in academic departments) and work across seven different units. Their research agendas are negotiated with their home academic departments. In addition, PIMSER is staffed by a core group of administrators and K-12 coordinators who maintain the network of schools, do outreach, provide assistance to faculty, and seek additional funding opportunities for the center.

In terms of the large-group discussion that followed the panel, participants stressed that these faculty appointments and arrangements really are exploratory, cutting-edge developments in higher education, which are resulting in an emerging and growing group of faculty who will have their own research agendas, grants, publications, and professional associations. At the same time, universities will be challenged to examine their commitments to these faculty appointments and arrangements over time. Will institutions, for example, rely on the commitment of individual faculty members who are passionate about and dedicated to teaching and learning, with the work fading into the background if these faculty members

decide to leave the institution? Or, will this commitment become embedded into the fabric of universities in a more permanent manner, and be supported and sustained over time? If so, what does such a commitment look like in terms of leadership, policy, and infrastructure support?

Key Breakout Discussions

In addition to the general sessions and larger group discussions, several breakout sessions were facilitated by APLU project staff, consultants, and participants. These sessions were designed to encourage and elicit more targeted discussions around challenges, issues, and promising practices related to institutional change processes and STEM teacher preparation at TLC institutions. While some sessions focused on specific topics, others provided role-alike opportunities (i.e., provosts together, TLC team leaders together) to discuss specific challenges and institutional agendas moving forward. This section briefly summarizes the major topics, findings, and participant observations that emerged from these breakout sessions, organized into five major discussion categories: (1) leading institutional change efforts, (2) faculty roles and rewards, (3) building institutional infrastructure and sustaining support, (4) transforming STEM undergraduate teaching and learning, and (5) promising teacher preparation practices and program strategies.

Leading Institutional Change Efforts

Align with external initiatives to move forward the STEM teacher preparation agenda.

Alignment with an external initiative such as SMTI was viewed as a potentially motivating strategy for participating institutions, and a way for leaders to move forward on their STEM teacher preparation agenda, even in the face of local resistance at some institutions. Participants shared several examples of local, regional, and national initiatives and partnerships that had played a key role in mobilizing their institutions around education reform, including the University of Cincinnati's leadership in the Strive initiative in the Greater Cincinnati and Northern Kentucky regions. Launched in 2006, Strive is a partnership of the education, business, nonprofit, community, civic, and philanthropic sectors that focuses on critical goals to ensure that every student succeeds from birth to college, and unites partners around shared issues, goals, measurements, and results, while actively supporting and strengthening strategies that work. Helping members of the campus community understand that they have a vested interest in these issues was seen as a critical institutional change strategy, as well as finding ways to position "outreach" activities more centrally to the core mission of the university.

Develop and clearly articulate a unifying vision.

Likewise, SMTI was framed by one discussant as providing participants with a collective leadership opportunity to help APLU institutions reinvent their current role in STEM teacher preparation. One of the biggest challenges, however, is that higher education is often seen as part of the problem, and not as a potential solution. Through these discussions, a major theme that emerged around facilitating change was the importance of SMTI institutions developing and clearly articulating a unifying vision around what they hoped to accomplish in STEM teacher preparation reform. A parallel was drawn between SMTI and the manner in which NSF's MSP projects have a common set of broad-based goals at the national level, but provide space for individual K-12 and higher education partnerships to evolve in specific directions that are appropriate locally. For example, SMTI and TLC leaders and faculty would likely universally support the improvement of undergraduate STEM education, as well as the notion that more and better prepared STEM teachers are needed in K-12 schools, but they would also likely envision different strategies and paths for reaching these goals.

Different levels of stakeholders need to realize that they have a vested interest in these issues—from regents to undergraduate students. There was substantial variation in institutional strategies and efforts to achieve this broader scope of engagement—with

some TLC institutions taking a more top-down approach, and others operating more at the grassroots level. And, while STEM faculty members and teacher education faculty members are ultimately in the most pivotal institutional positions for leading and implementing these initiatives, there was widespread agreement among participants that they need to be supported by department chairs, deans, and provosts, and work in environments that validate and reward their efforts. Thus, it is important that STEM teacher preparation be positioned within broader networks and communities of responsibility, with multiple partners who are able to leverage change when needed. Along this same vein, several participants noted the critical importance of having multiple "champions" in strategic positions on campus.

Have multiple "champions" in strategic positions on campus.

Faculty Roles and Rewards

Several TLC institutions reported that they were looking at (or planning to look at) their existing faculty appointment, promotion, and tenure policies, in light of the broader context of "public engagement" and expanded notions of faculty research and scholarship such as those defined by the Carnegie Foundation. At the same time, tensions were noted between balancing increased pressures for research productivity and increased emphasis on undergraduate education and public outreach—messages about fundamental institutional priorities that can be seen as conflicting. There was a general consensus among most participants that the climate seemed to be improving in a favorable direction toward STEM education at their institutions, particularly in light of the national spotlight given to STEM teacher shortages and the crisis in educational, economic, and scientific competitiveness. At the same time, each institution took a slightly different approach in its response. In some cases, reform efforts were being led and implemented by tenured faculty, while in others it was non-tenure-track faculty. In some cases it was science educators in discipline departments or science educators in education departments, while in others it was discipline-based education researchers, jointly appointed faculty, or other categories of professional instructional staff. At other institutions, the impetus for change was more top-down, coming from the highest levels of academic leaders and administrators. While these approaches were highly sensitive to the local culture, context, and resources at each institution, there was agreement that there should be a synthesis of effective models and best practices across TLC institutions that could be used for planning and benchmarking purposes.

Synthesize effective models and best practices across TLC institutions to use for planning and benchmarking.

One of the major themes that emerged in the discussion of faculty roles and rewards was the expansion of professional opportunities for non-tenure-track faculty (a general category that includes clinical faculty, lecturers, instructors, etc.), who frequently carry heavy administrative and teaching workloads with STEM teacher preparation programs and university engagement in K-12 schools. What do the career paths for these faculty members look like? What are the incentives for their leadership and involvement? Several institutions, including the University of Cincinnati, were looking at strategies for "professionalizing" these untenured faculty lines. Joint appointments and other types of "boundary-spanning" faculty positions were also discussed as promising practices, while still presenting their own challenges, since most of these staffing models and arrangements are not yet part of the formal culture at any institution. The importance of trying to achieve a "critical mass" of these types of faculty positions in disciplinary departments was stressed, although not seen as a likelihood in the near future given the current budget situation at most institutions.

Expand professional opportunities for non-tenure-track faculty.

Another strategy for introducing culture change in STEM education at universities is the expansion of appointments and roles for discipline-based education researchers. These positions can be pivotal in serving as change agents from within STEM departments as well as in leading course and curricular reform efforts, as they build upon a specific knowledge

base within the academic discipline. Experiences from the University of Colorado at Boulder were shared, as well as experiences from other TLC institutions that either had or were considering such appointments (predominantly physics education researchers). While the ranks of discipline-based education researchers are growing nationally, they are still relatively uncommon at APLU institutions (especially tenure-track or tenured faculty appointments). In looking into the future, there are STEM graduate students who are currently coming up through the ranks who are now assuming faculty positions and earning tenure by undertaking this research. How will this change the landscape for faculty in the STEM disciplines, both at the institutional and national levels (i.e., the role of disciplinary societies)? This represents a sea change from previous generations of STEM faculty, who were more likely to switch into the field of discipline-based education research after earning tenure through a more traditional research and scholarship agenda in the sciences.

Building Institutional Infrastructure and Sustaining Support

There were a number of discussions that focused on building the appropriate level of institutional infrastructure and sustaining support for STEM teacher preparation efforts. Many participants reflected on institutional successes and challenges with creating and administering STEM centers, or units on campus with the primary mission of promoting STEM education (e.g., expanding the STEM pipeline, supporting STEM teaching and learning, coordinating STEM-related outreach with K-12 teachers and students). Several examples were shared, including the Leitzel Center for Mathematics, Science, and Engineering Education at the University of New Hampshire, the Partnership Institute for Mathematics and Science Education Reform (PIMSER) at the University of Kentucky, and the Center for Science and Mathematics Education at Stony Brook University. In some cases, these centers directly reported to the provost through the creation of new positions such as the Senior Vice Provost for Engagement and Academic Outreach (New Hampshire) and the Associate Provost for Educational Partnerships (Kentucky), while in others, they were at the college/school level. Many institutions, including the University of Cincinnati and University of Maryland, College Park, shared that they were looking at plans to consolidate centers or better coordinate efforts across several STEM education-related centers on campus. Some of the center models shared were funded by external grants, some by endowments, some by central institutional funds for which colleges/schools could apply, and some by a combination of funding sources.

STEM centers can be "silo-busters" when they

- provide a common ground for focusing institutional efforts on STEM education
- provide a shared ownership for the institution's STEM agenda
- facilitate new pathways for internal and external collaborations
- create incentives and efficiencies for involvement by faculty, students and administrators

STEM center models were described as potential "silo-busters" when they were successful at providing common ground for focusing institutional efforts on STEM education, at engendering a sense of shared ownership for the institution's STEM agenda, at facilitating new pathways for internal and external collaboration, and at creating incentives and efficiencies for involvement among faculty, students, and administrators. Some institutions have had success with using their STEM center as the nexus for supporting faculty with the "broader impact" criterion in their NSF proposals, increasing the likelihood of more focused outreach efforts and decreasing the likelihood of unintentionally reinventing the wheel. Others have used their STEM centers as a hub for multidisciplinary faculty collaboration on activities such as STEM education-related research grants, joint scholarship and publications, and professional development on teaching and learning. Centers were also described as helping to simplify access to the university for external STEM education partners in the K-12, business, and philanthropic communities.

Another key discussion point was the importance of complete transparency in the sharing of data and information about STEM centers—where the funding comes from, how it is

spent, and who benefits. Deans, department chairs, and faculty can become suspicious of these efforts, especially when they perceive that money is being taken out of the colleges/schools to fund centralized institutional initiatives. It was suggested that institutions considering a new center (or changes to an existing center structure) conduct a benefit-cost analysis to weigh the relative benefits and costs of such investments. For example, what is the actual value-added of an institutional-level center versus college- or school-based efforts? In addition, there are certain administrative and procedural challenges that arise when undertaking multidisciplinary, cross-campus work, and they should be anticipated. For example, how are indirect costs allocated for faculty grants that are obtained through their affiliation with the center? Also, who will ultimately be responsible for collecting and analyzing data to evaluate the effectiveness and impact of the center, as evaluation is often an unfunded (or under-funded) but critical component of center work? (The University of Kentucky hired a research data analyst in PIMSER for precisely this reason.)

Transforming STEM Undergraduate Teaching and Learning

Perhaps not surprisingly, the discussions about reforms to STEM teacher preparation went hand-in-hand with discussions about reforms to STEM undergraduate education. Improving the environment for undergraduate teaching and learning in the STEM disciplines was seen as the key to attracting more majors, the pool from which potential K-12 teachers could be drawn. In particular, introductory STEM courses were seen as having a strong influence on student major and career choices, and a place where focused institutional efforts could yield a substantial pay-off in the recruitment and retention of STEM majors and teacher candidates. Several TLC institutions have been involved with large-scale course redesign initiatives through the National Center for Academic Transformation (NCAT), while others have used discipline-based education research to focus and inform their course redesign efforts. Participants also discussed whether it made a difference having tenure-track or tenured research faculty teaching these large introductory STEM courses, as they are often taught by lecturers, adjuncts, or graduate students. While there were diverse opinions on this issue, the general consensus was that students cared much less about these distinctions than faculty did, but would base their judgment on the effectiveness of the instruction.

Introductory STEM courses can have a strong influence on student major and career choices, and focused institutional efforts could yield a substantial pay-off in the recruitment and retention of STEM majors and teacher candidates.

Another issue related to the STEM undergraduate teaching and learning environment was the challenge of combating negative attitudes that often steer interested students away from K-12 teaching. For example, what do faculty members or academic advisors say when a STEM major expresses an interest in teaching? What kind of feedback or validation do these students receive? Is teaching presented as a viable career path for STEM majors, or as a fall-back option? Given these challenges, the importance of actively cultivating student interest in teaching was discussed, including co-curricular opportunities such as early field experiences in education, volunteer activities in K-12 classrooms, peer tutoring at either the college or K-12 level, and involvement in undergraduate teaching assistant programs.

TLC participants also shared information about institution-specific initiatives aimed at recruiting and retaining more STEM majors, including the Supplemental Instruction (SI) model (California State University, Fullerton and Lincoln University of Missouri), the Learning Assistant (LA) model (Florida International University and University of Colorado at Boulder), and the Merit Immersion for Students and Teachers (MIST) program (University of Illinois at Urbana-Champaign). While these approaches each have their own underlying assumptions and programmatic strategies, all embrace the goal of improving student learning in the STEM disciplines. Other programs that were discussed were focused more specifically on recruiting and transitioning STEM majors into teacher preparation

Initiatives to recruit and retain more STEM majors at TLC institutions:

- Supplemental Instruction (SI) model--*California State University, Fullerton and Lincoln University*
- Learning Assistant (LA) model--*Florida International University and University of Colorado at Boulder*
- Merit Immersion for Students and Teachers (MIST) program--*University of Illinois at Urbana-Champaign*

programs, including institutions with PhysTEC programs and NSF Noyce scholarship programs. One of the suggestions from the TLC retreat was for APLU to systematically identify and share best practices such as these across institutions, and to facilitate ongoing discussion and dissemination around the extent to which these efforts are leading to improved teaching and learning in the STEM disciplines, and, as an outgrowth, increases in the numbers of STEM majors and teacher candidates.

Promising Teacher Preparation Practices and Program Strategies

Finally, there were several breakout sessions that focused more specifically on STEM teacher preparation program components and strategies—including program marketing, student recruitment, and ongoing support for STEM teachers once they are in the classroom, including mentoring, induction, and professional development. The major themes that emerged from these discussions are summarized here:

Both **internal and external marketing efforts** can pose particular challenges for STEM teacher recruitment, as it can be difficult to generate resources, support, and enthusiasm in light of other competing institutional initiatives and priorities. **Forging ties with university press offices**, institutions are creating newsletters, op-ed pieces, press releases, Web sites and portals, and video marketing tools. Some programs are exploring the use of **social media outlets** such as Facebook and YouTube for recruitment efforts. Using teacher and **student testimonials** (e.g., interviews, pictures, voiceovers) were seen as particularly effective hooks for generating public support. Others are finding that STEM teacher candidates themselves are the most effective in marketing teaching to their peers on campus.

In **partnership and outreach work with K-12**, it is important that institutions **get information directly into the hands of classroom teachers and principals**. Information does not always flow downward from the district leadership level.

Creating formal links to community colleges (e.g., articulated programs) can be a useful teacher recruitment strategy for APLU institutions, since community colleges are even closer to where potential pools of teachers are, and because of the lower costs associated with educating students in this segment.

Providing STEM majors with early teaching experiences seems to be an important recruitment tool for teacher preparation (e.g., UTeach early field components, Learning Assistants model). In addition to formal programs, this can also include more informal outreach activities such as encouraging STEM majors to tutor K-12 students or volunteer at special K-12 school events such as science fairs.

Finding effective ways to incentivize STEM majors to consider teaching was also seen as a high priority, although even with the availability of funding, several TLC participants shared that they still had difficulty finding interested students. Some pointed to NSF's Noyce scholarship program as playing an important role in encouraging STEM majors to commit to teaching and providing significant funding as an incentive for them to do so. Others pointed to more institution-specific models such as the Learning Assistant program, which provides both an experiential component and financial incentive. Undergraduate research experiences carrying stipends were seen as another potential avenue for recruitment, as well as paid student teaching internships (which many alternative teacher certification programs, particularly for STEM career-changers, are already doing).

In terms of **new teacher retention**, some institutions have found success with **connecting new teachers with scientists** who are working in industry, research faculty in labs, and other members of the scientific community, who can provide teachers with knowledge applications and a deeper understanding of how scientific research and discovery can be mapped back to the curriculum they are teaching in the classroom.

TLC participants stressed the importance of **bringing STEM teachers (especially novice teachers) together as part of a larger community** to provide opportunities for ongoing support, professional development, collaborative planning, and peer-to-peer mentoring. Several institutions have built virtual online communities, either real-time or asynchronous, for bringing teachers together and providing them with an ongoing link to the university. Such activities were seen as particularly effective for reaching teachers in geographically dispersed locations, including rural communities.

One of the major challenges that institutions face in ongoing **professional development** for STEM teachers is providing access to master's level content courses, which tend to be offered during K-12 teacher work hours. Many institutions are looking at **more flexible delivery formats** in their work with K-12 teachers—weekend and summer courses, web-based and video-based offerings, and after-school cohort programs that are offered on-site in the schools.

Cross-Cutting Issues and Themes

A number of cross-cutting issues and themes emerged through these discussions, which were synthesized at key points during the retreat through report-outs and a culminating reflection session. Four such themes are summarized below: (1) the challenges associated with engaging presidents, provosts, and key institutional leaders in this agenda, (2) the unique contributions that APLU institutions can make to STEM teacher preparation at the national level, (3) the importance of embedding STEM teacher preparation in the broader context of STEM teaching and learning, and (4) the need for continued institutional innovation and transformation around STEM teacher preparation.

Engaging Institutional Leaders

One of the key institutional challenges identified by TLC participants is the need to increase the level of involvement in and ownership for STEM teacher preparation on the part of presidents, provosts, and other senior higher education leaders. This is important because institutional leaders can play an integral role in shaping the institutional climate for STEM teacher preparation and in determining how it will be viewed and valued by the broader campus community. It was suggested that strengthening the policy focus of SMTI—including institutional as well as state and federal policies—may encourage more university leaders to become involved in the broader initiative. In addition, it was suggested that the TLC project continue to provide meetings, conferences, and similar occasions for senior leaders to convene with their peers around these issues, as well as visible leadership opportunities for demonstrating their commitment. APLU is in a unique position to play this role given its role in STEM education reform through SMTI, its involvement in national and state higher education policy issues, and its ability to convene multiple institutions and multiple constituents at various leadership levels: chancellors, presidents, provosts, academic deans, other administrators, and faculty.

Unique Contributions of APLU Institutions

A number of conversations focused on the unique contributions that APLU institutions are making to STEM teacher preparation and STEM education at the national level. This not only includes the annual preparation of thousands of STEM teacher candidates, but also faculty scholarship associated with teacher preparation and discipline-based education research on STEM teaching and learning. APLU institutions currently enroll more STEM students than any other type of higher education institution in the United States, and most have large colleges/schools of education as well. Collectively, what is the nature of their impact on STEM teacher preparation at the national level? Do APLU institutions share a common set of aspirations or expectations for their STEM teacher preparation programs or for the STEM teacher candidates they produce—ones that set them apart from other types of institutions? For example, can APLU institutions provide evidence that they graduate science teachers who have had the experience of doing "real" science at a research university, and who can then bring these perspectives into their K-12 teaching? Or, can APLU institutions claim the distinction of graduating "teacher-leaders" who are not simply classroom technicians with a good understanding of science, but who are sufficiently well-educated to be truly effective teachers and leaders?

Links to STEM Teaching and Learning

STEM teacher preparation programs are embedded within the broader STEM teaching and learning environment at each institution. This plays out differently at each institution according to factors such as institutional mission, program size and emphasis, campus resources, organizational and structures, faculty appointments, and student populations served. Continuing to find ways to link teacher preparation and work with K-12 schools to the core mission of the university seems to be an important goal for TLC institutions—as often these institutional activities are regarded as peripheral outreach and service rather than core academic initiatives. Many institutions are linking their STEM teacher preparation efforts to broader STEM undergraduate education reforms—as improvements in the teaching and learning environment should affect the number and quality of STEM majors and have a resulting increase in the STEM teacher candidate pool. In order to facilitate this work, some institutions have created "boundary-spanning" faculty positions including joint faculty appointments, education appointments in STEM departments, and STEM appointments in education departments. Others have launched STEM centers that facilitate cross-campus collaboration and have the primary mission of promoting STEM education—expanding the STEM pipeline, supporting STEM teaching and learning, and coordinating STEM-related outreach with K-12 teachers and students. Such efforts not only help engage the broader campus community in STEM education, but they can also serve as an important entrée into interdisciplinary scholarship at the institution, tying these efforts to institutional-level teaching and learning priorities and faculty work that is valued in the academy.

Need for Innovation

The traditional university "cohort" education model for preparing STEM teachers (in which classes are offered at set times, and sometimes only once per year) warrants attention, particularly for non-traditional students such as working adults and career changers. This issue will become increasingly pronounced as student demographics in higher education continue to shift and alternative providers, including for-profit institutions, continue to enter the teacher preparation market with more flexible programs. Many APLU institutions, such as Indiana University-Purdue University Indianapolis (IUPUI), have implemented programs that are non-traditional pathways to STEM teacher certification. For example, the Woodrow Wilson Indiana Teaching Fellows program (of which IUPUI is a participant) recruits individuals who have already earned at least a bachelor's degree in a STEM discipline. Fellows receive a $30,000 stipend, enroll in a master's program leading to certification, and commit to teaching secondary mathematics or science in a high-needs Indiana school for at least three years. The University of Maryland, College Park has developed a model in partnership with a local school system providing a paid internship in which career changers spend half the day in a secondary mathematics or science classroom as the teacher of record, and the other half in university courses which will lead to full certification. How do APLU institutions demonstrate the value-added that these alternative teacher preparation programs contribute? Are there other exemplary non-traditional pathways to STEM teacher certification that APLU institutions can learn from?

Recommendations for APLU

At the conclusion of the retreat, Ann Austin and Ellen Chaffee led a conversation eliciting participant reflections from the sessions, with a particular emphasis on next steps for APLU and TLC institutions around the STEM teacher preparation agenda. The following three "calls to action" emerged from that discussion:

APLU should continue to frame and communicate the key goals and messages of this agenda.

The notion of the "North Star" was reintroduced—the guiding vision around which participants of this initiative can rally. The importance (and challenges) of creating a unified vision at both the institutional and national meta-levels were discussed. At the same time, there were diverse perspectives on what this vision should actually entail: Producing more and better prepared mathematics and science teachers? Increasing higher education's perceived value of the K-12 teaching profession? Increasing the quality of STEM teaching and learning at all levels of education: K-12, undergraduate, and graduate? Participants also stressed the importance of APLU thinking about potential audiences for this message beyond TLC and SMTI institutions. Are there particular permutations of this message that are appropriate for different contexts and audiences? (As a corollary example, it is true that higher education plays a major role in both liberal education and workforce development, but these somewhat disparate views of higher education resonate differently with different stakeholder groups and constituents.) The metaphors of "campaign" and "movement" were also discussed in this context, as well as encouragement for APLU to continue to generate more public "noise" about this important work. APLU was seen as being in an ideal position to help articulate policy positions and preferences that can serve as a national platform for advocating for federal and state support of STEM teacher preparation programs in higher education.

APLU should continue to build collaborations and make connections both inside and outside of this initiative.

Participants stressed that APLU should continue to provide opportunities such as the TLC retreat for interaction between provosts (and other senior institutional leaders) and STEM teacher preparation program directors and faculty. Such settings have an important role in further legitimizing this work and helping to raise its visibility both at the national level and back at their home institutions. In addition, it is important to provide APLU presidents and provosts with opportunities to engage in these issues with their own same-role colleagues from other institutions. This is an additional way to help build project visibility and extend leadership capacity and support nationally. Participants encouraged APLU to continue to build upon existing collaborations with organizations such as the American Physical Society (APS) and American Chemical Society (ACS) and to continue to pursue broader networks and strategic partnerships as part of the SMTI effort, including other higher education associations, discipline associations, national initiatives, and funding sources. National organizations for education deans and arts and sciences deans were also mentioned as potential allies in these efforts. In addition, collaboration with highly visible

partners such as the National Governor's Association (NGA) and members of Congress could help raise the profile of future SMTI meetings even more—further energizing the movement and further increasing the likelihood of enrolling and sustaining top university leadership in this initiative.

APLU should continue to facilitate the practical exchange of information that is occurring around strengthening institutional capacity for and commitment to STEM teacher preparation.

Initiatives such as TLC and SMTI have provided opportunities for APLU institutions to share common challenges around STEM teacher preparation and strategies for expanding and improving their efforts. An important function of APLU could be to create a clearinghouse for evidence-based best practices at APLU institutions. In addition to data on effective STEM teacher preparation programs, a particular area of interest is in collecting data on institutional policies, practices, and decisions that have helped move the dial on STEM teacher preparation at APLU institutions, including resource allocations, campus infrastructures, tenure and promotion policies, and faculty appointments and staffing models (including the role of joint appointments and non-tenure-track faculty). At the same time, there were cautions about solely advocating for the replication of "prescribed" models for preparing STEM teachers at the expense of encouraging institutional innovation, developing new preparation models, and generating new knowledge and scholarship in the field. In addition, there is a growing network of institutional leaders and program faculty who are well-steeped in knowledge and experience of this work, and who are accustomed to sharing their expertise with peers undertaking similar efforts at other institutions. As APLU looks to build knowledge around effective STEM teacher preparation programs and to disseminate best practices, it will be important to find platforms for formally identifying and engaging these individuals in supporting, informing, and promoting this work across APLU institutions.

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The TLC is part of the Science & Mathematics Teacher Imperative (SMTI), an initiative of the Association of Public and Land-grant Universities (APLU) and the nation's public research universities to transform middle and high school science, technology, engineering and mathematics (STEM) education by preparing a new generation of world-class science and mathematics teachers.

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