PROCEEDINGS OF THE FIFTH ANNUAL MATHEMATICS TEACHER EDUCATION PARTNERSHIP CONFERENCE

FROM IMPROVEMENT TO TRANSFORMATION

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Preface

These proceedings are a written record of the presentations and papers presented at the Fifth Annual Mathematics Teacher Education Partnership Conference held in Atlanta, Georgia, June 26-28, 2016. The theme for the conference was "From Improvement to Transformation." We are pleased to present these Proceedings as a resource for the mathematics and mathematics education community.

www.mte-partnership.org

[1] W. James Lewis and Robert N. Ronau participated as members of the MTE-Partnership Planning Team while serving at the National Science Foundation. Any opinion, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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INTRODUCTION

The MTE-Partnership Story as Revealed through Its Conferences: An Overview of the Partnership and Its 2016 Conference

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The MTE-Partnership was formed by the Association of Public and Land-grant Universities (APLU) in 2012 to address a major problem in secondary mathematics teacher preparation, an undersupply of new secondary mathematics teachers who are well prepared to help their students attain the goals of the *Common Core State Standards for Mathematics* (CCSSM) (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) and other rigorous state mathematics standards. This consortium of over 90 universities and over 100 school systems has a common goal of transforming secondary mathematics teacher preparation using the Networked Improvement Community design (Bryk et al., 2015). This essay will provide a brief overview of how the Partnership has evolved, told through the lens of the past four MTE-Partnership Annual Conferences, outline the goals and accomplishments of the fifth conference held in 2016, and conclude by looking at future directions for the MTE-Partnership.

The Development of MTE-Partnership through the Lens of Past Conferences

While the work of the MTE-Partnership carries on throughout the year, the annual conferences have served as important landmarks where many of those active with the Partnership gather together to reflect on the progress that has been made and set forth plans for the coming year. Indeed, the initial concept for the MTE-Partnership was formulated by participants at the 2011 conference of APLU's Science and Mathematics Teaching Imperative (SMTI), which focuses more generally on improving mathematics and science teaching. The focus of that conference was on changes needed in higher education to effectively respond to the CCSSM, which had just been released. Several speakers, as well as a working paper released prior to the conference (Wilson & Martin, 2011), discussed the need for significant changes in mathematics teacher preparation. Several mathematics educators attending the meeting discussed the specific needs at the secondary level, and a white paper was submitted to the

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SMTI Executive Committee proposing the formation of a new project focusing on preparing secondary mathematics teachers to help their students meet these new, more rigorous standards.

Over the coming months, a planning team was formed to organize what became the MTE-Partnership. In response to an invitation to universities to apply for membership to the partnership, 38 teams representing 30 states became the founding members. (Since that time, an additional team has joined the partnership, and several teams have expanded to include additional campuses, bringing the total number of campuses to over 90.) Additionally, each team was required to include at least one school district partner. As the invitations to apply to join the partnership went out, applicants were asked to plan to attend the first conference, held in April 2012 in Atlanta.

2012 Conference

As a part of the application process to join the MTE-Partnership, applicants completed a needs analysis based on an initial framework designed by SMTI (Coble, 2012), including both their core values for secondary mathematics teacher preparation as well as their progress in meeting those core values. Their responses were used to create an initial draft of guiding principles for the MTE-Partnership that became the focus of discussion at the 2012 conference. Following the conference, the *Guiding Principles for Secondary Mathematics Teacher Preparation* (Mathematics Teacher Education Partnership, 2012), since updated in 2014, were released as to “describe a shared vision to be explored and refined by the MTE-Partnership and others involved in preparing secondary mathematics teachers” (p. 1), thus serving as the central organizing document for the Partnership.

At the 2012 conference, participants were also asked to identify potential challenges in meeting those principles. This became the first step in developing the problem space for the Partnership; a follow-up survey of conference attendees was used to further define this list of challenges, and a subsequent survey was sent to representatives of all the partnership teams, asking their judgment of both the importance of each item on the list to their team, as well as their team’s interest in attempting to address each item. The results from this survey were used to identify a set of priority challenges to be addressed by the partnership. This emerging set of high-priority challenges was presented to the partnership for further reaction, which led to the formation of working groups to address a set of four highest priority challenges (Martin & Strutchens, 2014). Over the coming months, members of the working groups wrote draft white papers providing a review of relevant literature and initial recommendations for actions.

As members of the planning team reflected on the 2012 conference, they recognized that a stronger design was needed for the Partnership to address several needs, including (a) the need to maintain the engagement of the teams in the work of the Partnership, so that everyone felt that had a role to play, and (b) the need to maintain a focus on disciplined inquiry consistent with the mission of universities (Martin & Gobstein, 2016). One design that was investigated, based in part on the recommendation of a reactant at the 2012 conference, was the Networked Improvement Community (NIC) model being developed by the Carnegie Foundation for the Advancement of Teaching (cf. Bryk et al., 2015). The decision to reconstitute the Partnership as a NIC was ratified by the membership in Spring 2013, leading up to the 2013 Annual Conference. The high-priority challenges being addressed by the working groups were reconstituted as "primary drivers" that would help the Partnership reach its aim of producing more well-prepared secondary mathematics teachers; see details in the first two (leftmost) columns of Figure 1.

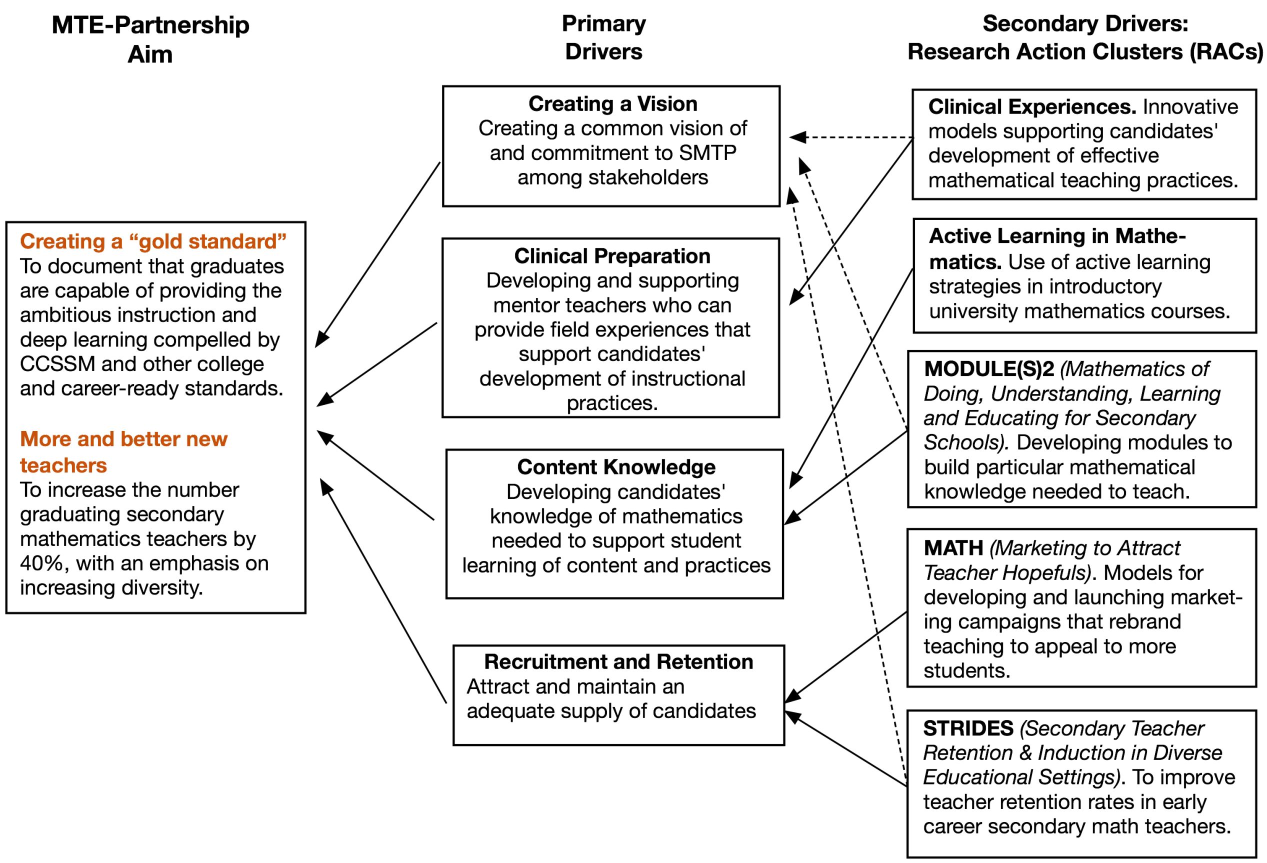

Figure 1. The MTE-Partnership driver diagram.

2013 Conference

The 2013 Conference, held in early June in St. Louis, focused on learning more about the newly-adopted NIC design and developing the problem space for the Partnership in alignment with that design. Close to 90 participants gathered into four breakout groups organized by the four primary drivers; each participant was asked to select one of the working groups. Over the course of the conference, the breakout groups provided feedback on the respective white paper for their chosen primary driver, identified possible aims and secondary drivers relevant to that aim, and discussed possible measures that might be used to track progress towards the aim.

The work of the breakout groups culminated with the identification of potential interventions that were then presented to the conference participants. Across the four groups, thirteen potential interventions were presented in a final session of the conference in which participants were asked to physically gather around the posters of their highest priority potential areas of action as a first indication of interest. Following the meeting, the MTE-P Planning Team eliminated or consolidated several of the areas based on that initial feedback, and a subsequent survey sent to all team leaders further narrowed the list to five interventions as being of the most importance and interest to MTE-Partnership.

In fall 2013, partnership teams were invited to apply to join “research action clusters” (RACs) organized to develop each of these five interventions. These RACs have become the primary structure for participation in the MTE-Partnership. A “boot camp” was held in November 2013 with RAC leaders to launch their work. Plenary sessions on tenets of NIC design were interspersed with breakout sessions in which participants met by RAC to apply those tenets to defining more specific driver diagrams, aim statements, measures to track progress, and an initial action plan for the RAC. Note that one RAC was later disbanded as consensus was not reached on a plan of action, and an additional RAC was formed summer 2015 to address an emergent area of concern, induction of candidates into the profession. The current list of RACs, along with their connections to the primary drivers is shown in Figure 1. Each RAC incorporates the NIC design, using improvement cycles to develop interventions addressing its identified aim.

2014 Conference

The 2014 conference, again held in early June in St. Louis, was focused around the work of the RACs. RAC members met in small groups to review their initial work in forming an aim and driver diagrams and to begin planning specific improvement efforts to be undertaken in the coming year using “Plan-Do-Study-Act” (PDSA) cycles as a model; see Figure 2. PDSA cycles describe a process of planning, implementing, collecting data, and revising in alignment with the NIC design. Additional sessions focused on increasing understanding of the NIC design and exploring issues related to secondary mathematics teacher preparation. A final poster walk allowed RACs to share their progress with members of other RACs.

Following the conference, the work of the Partnership was largely focused on RAC-level work, as RACs built on their progress at the conference throughout the following academic year, using a combination of virtual, on-line, and face-to-face communications. Additionally, the planning team continued to meet periodically to ensure collaboration across the RACs and to maintain focus on the Partnership aim. A working group began meeting to develop common measures across Partnership teams to track progress towards the aim. Several surveys were developed addressing key variables, including candidate production and targets, a self-assessment to be completed by team leaders, and a self-assessment to be completed by program completers. These instruments were refined and piloted over the following academic year.

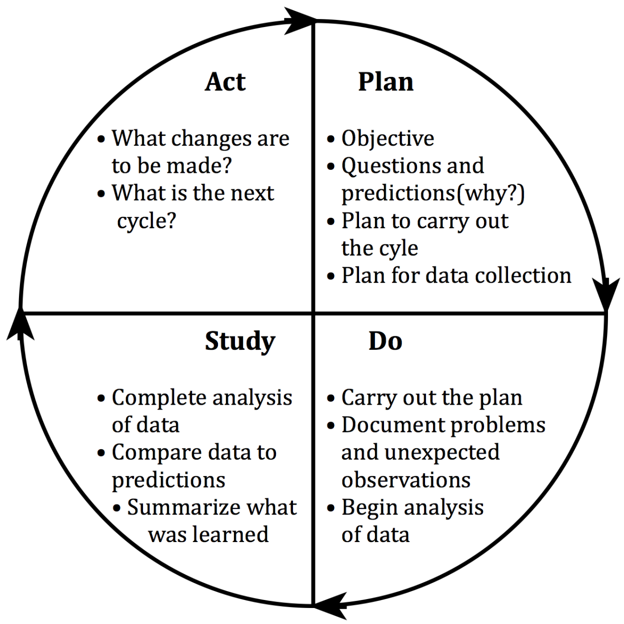

Figure 2. The Plan-Do-Study-Act (PDSA) Cycle. (Adapted from Langley et al., 2009)

2015 Conference

The 2015 Conference was held in Fullerton, CA in late June with a continuing focus on the RACs. Following feedback to the 2014 conference, the worktime spent meeting in RACs was expanded. The aforementioned new RAC on improving the retention of program graduates in the profession was also launched. However, one of the major developments at this conference was the increased participation by members of the California State University system, which expanded its participation to include all 22 campuses that provide teacher preparation. This created an influx of new participants, and a special session was held to introduce them to the Partnership and the NIC model. The RACs each produced one-page “promotional sheets” designed to encourage these new participants to join in their activities.

The 2015 conference also introduced an emerging emphasis on program transformation, reflecting the challenges programs face in moving beyond making changes based on the one or two RACs in which they are actively engaged to aggregating the findings of multiple RACs to undertake the broad-scale changes needed to ensure both the necessary quantity and quality of secondary mathematics teacher candidates. Issues include ensuring that the human capital is available to participate in the improvement effort, that secondary mathematics teacher preparation is a priority across stakeholder groups, and that institutional resources and support structures are provided. The proposed solution is to provide tools and techniques to support institutions in creating "strategic pathways for transformation" in which they scale up their use of the approaches designed by the RACs.

This summary of progress of the progress of the MTE-Partnership over the course of its first five conferences now sets the stage for a discussion of the 2016 conference.

Goals of the 2016 Conference

The 2016 MTE-Partnership Conference, held late June in Atlanta, GA, had four primary goals building on the work done in previous years. Each goal is discussed in turn, along with how the structure of the conference supported that goal.

1. To build focus on the transformational change needed for teams and programs to achieve the partnership aim. Following the 2015 conference, a working group was formed to begin development of strategies supporting transformational change, as discussed above, possibly culminating in the creation of a new RAC. Members of the working group presented a panel discussion of issues related to transformational change at the conference, and a series of brief research reports was designed to share on-going work across the partnership.

2. To make equity and social justice more explicit as an essential component of the partnership aim. While attention to equity and social justice is embedded in the *Guiding Principles* and in the work of many of the RACs, members of the planning team noted that this is not visibly a part of the Partnership aim or drivers. Thus, a decision was made to begin to make the focus on equity and social justice more explicit, with discussions at the conference serving as a starting point. A work session was held at the conference to begin those discussions. Moreover, during their worktime at the conference, each RAC was charged with considering how issues related to equity and social justice could be made more visible in their goals and work, and to then reporting on their progress in this area in the closing session.

3. To build a sense of joint purpose and identity across the partnership. Given that much of the work of the MTE-Partnership is now focused on the RACs, in some cases it has become challenging to maintain a sense of common purpose and identity for the Partnership; participants may tend to focus more on the problems that interest them, particularly the work of the RACs in which they are involved (Martin & Gobstein, 2015). While the RACs may be their specific focus for participation, there is much to be gained by emphasizing the broader structure of the Partnership, including learning from and with the other RACs and considering the more general context for the work of the RACs.

At the conference, general sessions included to emphasize the sense of joint purpose and identity. A keynote address by Suzanne Wilson provided national context in which to consider the work of the Partnership. Overview sessions by the project leaders emphasized the overall aim and purpose of the Partnership, as well as its accomplishments. In the opening and closing sessions to the conference, the RACs shared progress made in achieving their goals. Finally, three reactants provided insights gleaned from observing the work of the Partnership across the RACs.

4. To accelerate the work of the five Research Action Clusters (RACs) towards their aims. Arguably the major goal of the conference was to support the work of the RACs. Having an extended period (more than 8 hours) over several days in which to collaborate face-to-face can provide an important stimulus to their work. The RACs spent time reflecting on their past progress and making plans for the coming academic year. In addition, a panel on the NIC design and improvement science shared insights from members of the Clinical Experiences RAC who attended a series of workshops offered by the Carnegie Foundation to support groups using the NIC model.

Conclusions and Next Steps

The activities for the coming academic year and beyond build firmly on the foundation of the work done at the 2016 Annual Conference. The transformation change working group met after the conference and will continue to develop plans to create a formal research action cluster focusing on supporting institutional change. Discussions related to equity and social justice will continue after the conference, with a major focus on how to best organize continuing work in this area. While a distributed approach is essential in furthering the work, a new working group on equity and social justice is being considered to build cross-RAC focus. The sense of joint purpose and identity of Partnership participants continues to be nurtured through efforts of the planning team to coordinate and focus the work and through Partnership-wide communications, such as the *Partnership Pipeline*, a newly-launched quarterly newsletter. Finally, the RACs continue to meet both virtually and face-to-face to meet their aims.

While much of the activity of the MTE-Partnership now occurs within the RACs, over the years the conferences have served an important role in establishing and catalyzing the Partnership's vision and direction. Moreover, they have continued to serve an important role beyond supporting the work conducted in RACs, as they have brought together participants across the RACs to share their on-going work. This has both provided opportunities to cross-pollinate efforts across the RACs but also to develop a sense of shared identity and commitment to the broader MTE-Partnership effort, beyond participation in one aspect of its work.

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Overview of the Conference

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The MTE-Partnership emerged because the work of changing secondary mathematics teacher preparation is very difficult, particularly because of the lack of valid and reliable measures available to guide the process. This group stands apart from previous efforts because of the emphasis on connecting local efforts to network understandings and network understandings to local efforts. That is building a community of learners, learning together. Through well-connected efforts within the network, local experiments are leveraged to reveal powerful results in which the focus is transformation. Transformation is more than just taking to scale, but strengthening the relationships between those involved.

MTE-P uses the Networked Improvement Community (NIC) model, developed by the Carnegie Foundation for the Advancement of Teaching (Bryk, Gomez, & Grunow, 2011; Bryk, Gomez, Grunow, & LeMahieu, 2015), to guide the numerous and complex activities of the member partners, and to help them to transform their efforts into meaningful results. NICs are intentionally designed social organizations that are: (1) focused on a common aim, (2) guided by a deep understanding of the problem and a shared approach to solve it, (3) disciplined by the methods of improvement research to develop, test, and refine interventions; and (4) organized to accelerate interventions into the field and to effectively integrate them into the field.

These proceedings are of the fifth MTE-P conference. We have moved past the initial organizational startup issues and are rapidly learning how to translate individual partnership efforts into nation-wide results (Martin & Gobstein, 2015). Consequently, the theme for this conference is “From Improvement to Transformation.” In this case, Transformation is more than just taking to scale, but strengthening the relationships between those involved; that is strengthening the NIC to better support and share the work. As you will discover in these proceedings we have five research communities—Research Action Clusters (RACs)—that have developed and implemented strategies that span universities and stages and now are beginning to share results.

[1] Ronau contributed to this paper while serving at the National Science Foundation. The comments expressed here are those of the author and do not necessarily reflect the views of the National Science Foundation.

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This fifth conference was designed to achieve four goals: (1) to build focus on the transformational change needed for teams and programs to achieve the partnership aim; (2) to make equity and social justice more explicit as an essential component of the partnership aim; (3) to build a sense of joint purpose and identity across the partnership; and (4) to accelerate the work of the five Research Action Clusters (RACs) towards their aims. To provide individual consideration and support to goal 4, the time of the conference was organized to provide substantive work time for the RACs. Also, several plenary and social events were scheduled to achieve the first three goals. Further, the plenary sessions were designed to provoke the work within the RACs to explicitly address issues of equity, underdeveloped to this point by the MTE-Partnership. Participants were especially challenged to move beyond individual work and seek ways to elicit systemic change, that is, to move from improvement to transformation goals. This executive summary will serve to identify the sections of the Proceedings and provide a brief overview of each entry.

Plenary Session

After attendees were welcomed and the conference opened by MTE-Partnership co-directors Dr. Gary Martin and Mr. Howard Gobstein, Dr. Suzanne Wilson delivered a talk in the first of the plenary sessions, “Staying the course: Transforming mathematics teacher preparation in responsive, responsible ways.” She challenged MTE-P to face our critics by using research, meaningful measures, coordinated cross-institutional efforts, and persuasive anecdotes to guide the public face of mathematics teacher preparation. Dr. Wilson related how lack of a common vision and meaningful measures place us at a disadvantage as we attempt to revise mathematics teacher education programs. Proxy measures may not be useful measures to help guide change in teacher preparation. O’Neil (2016) in her work “Weapons of Math Destruction” details how simple proxy measures commonly used to evaluate teacher work can cause great harm. O’Neil shows how simple, indirect and proxy measures can create systems that do not measure what they claim, inappropriately punish the targets (teachers and schools) of those measures, contribute little to improving quality of those systems, and resist transparency that might lead to meaningful change. Dr. Wilson stressed that we should continue work together to make small, well-documented interventions to incrementally move the field forward. We can transform teacher preparation by tweaking what we do based on current theory and guided by valid and reliable measures. MTE-P’s current efforts RACs are a very appropriate tool to take on this task. Dr. Wilson’s talk is reported in these proceedings by Robert Ronau.

After Dr. Wilson’s talk, each RAC provided a brief update on their progress over the past year. The remainder of this first afternoon of the conference was dedicated to RAC work time.

Panel Talks

The day concluded with a panel talk that chiefly served to foster conversation about the intersection of issues of equity, diversity, and social justice and the work of the MTE-Partnership. Approximately one-half the conference attendees joined this early evening discussion. Many questions and needs emerged during the discussions, and strong support for the development of a working group on equity, diversity, and social justice was expressed.

The morning of the second day began with the second panel talk, "A Deeper Dive into Plan-Do-Study-Act Cycles and Measures," a discussion that focused on the application of PDSA cycles and the measures, tools and strategies developed to support the improvement science process. This plenary was designed to continue to increase the community's understanding of the NIC research design. The presenters, Michele Iiams, Ruthmae Sears, Mark Ellis, and Marilyn Strutchens had recently attended a NIC workshop by Carnegie. Here, they shared both some important elements of the PDSA research cycles and their struggles and successes as their teams implemented the research cycles in their locales and shared the results across sites.

Addressing conference goal one, to build focus on transformational change, another panel talk focused on local efforts to transform teacher preparation at their institutions. The "Pathways to Program Improvement" plenary included Mark Ellis, Margaret Mohr-Schroeder, De Vonne Smalls, and Wendy Smith, with discussion by Robin Hill. Each member of this panel shared their experiences with respect of changing their secondary mathematics teacher preparation programs. Some of the challenges that they faced were similar; however, panel members described very different strategies and activities that drove change in their situation. All panel members indicated that the work has just begun and much more effort will be needed to reach their goals.

After lunch on the final day of the conference, three members of the national community concerned with the preparation of secondary mathematics teachers shared their experiences and reactions to the conference in a final panel talk, Karen King, Diana Suddreth, and Jim Lewis. These three individuals were invited to freely participate in the conference activities to assess the progress of MTE-P and to share their perspectives with the participants. Although the reactants praised the progress made by MTE-P, each was able to suggest additional perspectives and/or actions that the initiative might consider. For example, Dr. King suggested that MTE-P groups investigate research outside of mathematics education to learn about strategies and their potential unintended consequences with respect to diversity training. Ms. Suddreth encouraged MTE-P teams to broaden their engagement with their communities. Finally, Dr. Lewis suggested that the time may have arrived for MTE-P as an organization to reflect on the goals initially established by the partnership and on the work that has been accomplished to evaluate and re-assess the nature the of the task at hand, the fatigue of the participants after five years of continual struggle, and the transformative work that lies ahead to strategically identify and pursue potential levers of evolution that could accelerate the effectiveness of the effort. The comments of these reactants are reported in these proceedings by Brian R. Lawler.

Research Action Cluster (RAC) Reports

Early in the growth of the MTE-Partnership, RACs were formed to address specific problems identified in the driver diagrams. RACs were designed to be the active agents of MTE-P, moving the effort from discussion to action. RACs provide the focus and impetus to take the initiative from organizing to theorizing to transforming.

In advance of the conference, each RAC submitted a "promo sheet" designed to orient new conference participants to the work of the RAC, and update long-time MTE-P members. These promo sheets are available online at the APLU MTE-P website, linked in these proceedings at the top of the RAC Reports. During the conference, the RACs had approximately 8 hours of structured work time. The RACs submitted reports for these proceedings that identified the work of the RAC to date, what was accomplished during the conference, and their next steps moving forward.

The Clinical Experience RAC (CERAC) consists of 24 partnerships organized into three sub-RACs: Methods, Paired Placement, and Co-Planning and Co-teaching (CPCT). The Methods sub-RAC is next focusing on creating a Lesson Design modules. Paired Placement is revising their workshop for teachers and preservice teachers, as well as developing manuscripts and seeking funding. And CPCT is working to scale up their measures work. All members of the RAC intend to pay explicit attention to equity and social justice issues in the next iterations of their modules. Each Sub-RAC developed its own research questions and PDSA cycles; however, overlapping interests, such as the Mathematics Teaching Practices, and measures, such as the $MCOP^2$, are used to drive a common focus across all partners in CERAC.

The Actively Learning Mathematics (ALM) RAC focuses on improving undergraduate mathematics in Pre-calculus through Calculus 2 (P2C2). ALM has developed class materials and a student survey that is available to all MTE-P partners. Currently, 14 partner institutions are participating in ALM. The ALM RAC reorganized to help manage growth, into course- and topic-specific groups such as Calculus I and Lesson Study in Calculus. In the coming year, one important element of their work will be to organize site visits.

The Mathematics of Doing, Understanding, Learning, and Educating for Secondary Schools MODULE(S^2) RAC is focused on the development of prospective secondary mathematics teachers' knowledge of mathematics content needed to support student learning. The MODULE(S^2) RAC has developed modules in Geometry (3), Modeling (3), and Algebra (3 in progress) and Statistics (1). These modules are being piloted and are available for partner institutions to pilot.

The Marketing to Attract Teacher Hopefuls (MATH) RAC has completed the development of its recruiting materials which are available on their website at bit.ly/MATHImplGuide. Eleven partner institutions have developed PDSA cycles for recruitment at their local sites and shared their results at whole group meetings. In addition to sharing out, the RAC discussed new initiatives and next steps for the RAC with attention to both identifying funding to support recruitment work and research and to address the MTE-P commitment to equity and social justice.

The Secondary Teacher Retention & Induction in Diverse Educational Settings (STRIDES) RAC was recently formed and is off to a fast start. At this conference the STRIDES analyzed the results from a pilot survey (*n*=66) and used those results to revise a survey to be sent to students in all partner institutions. The STRIDES RAC divided into subgroups based on a change idea focus: (1) Long-Term Collaborative Groups for Early Career Teachers, (2) Role of Administrators and Site-Based Colleagues, and (3) Training & Supporting Teacher Mentors. Currently PDSA cycles are being developed within each of these three groups for implementation in the coming months.

Research Presentations

Research initiatives have emerged from the work of the RACs as team members designed and implemented studies about their work. As part of the announcement for the fifth MTE-P conference, for the first time, we included a call for research papers. These papers were reviewed and presented at the conference by the authors. Some presenters only elected to submit abstracts of their talk for the proceedings, others submitted a complete and revised paper for publication. The proceedings have grouped all the talks, abstracts and papers, as they were organized by themes for the conference. Here we report only on the full papers published in the proceedings, organized by themes as they were grouped for presentation at the conference. The papers are briefly mentioned below, grouped by these themes, and can be found in their entirety in the proceedings.

Building a common vision and/or partnerships across stakeholders

Garrett and Tameru report the results of a study examining the existing mathematics teaching practices at their institution. They categorized exam items from precalculus and calculus courses on five types of thinking necessary to respond. Students were infrequently expected to think beyond recall or application of known procedures.

Sears and Burgos investigated the process of collaboration among faculty members in the College of Education and the Department of Mathematics and Statistics in the development of middle school teacher's mathematical content knowledge for teaching. And Veneciano and Doerger report on a third effort to build common vision among the newly established MTE-P Hui team. They focused on recognizing commonalties and established shared goals.

Mathematical content knowledge (including mathematical knowledge for teaching)

Three papers in this collection focused on understanding developing mathematical understanding of future mathematics teachers. Burger and Markin report on a pilot study that explored conceptual approaches to learning Calculus I. They moderated their lessons to lead students to deeper understanding of targeted concepts by activating familiar prerequisite knowledge. Deka reported on the implementation of the Geometry Modules that were ready for pilot from the MODULE(S^2) RAC. She shared how students reacted to the modules, the challenges experienced teaching the course, and discussed whether the approach seemed to make a difference in the preparation of mathematics teachers. Smith examined the mathematical content knowledge—specifically of geometry—of pre-service and high school mathematics teachers. Her findings suggested domains of Geometry Teaching Knowledge that could be emphasized in pre- service and professional development.

Knowledge and use of educational practices

Bowers and Smith report on how they modified the $MCOP^2$ observation protocol to examine the implementation of the products of the Active Learning Mathematics RAC at the university level. Their study suggested that the $MCOP^2$ student survey they created appears to be reliable. Secondly, the student survey appears to be useful for identifying what students believe are specific value-added aspects of active learning.

A second report by Smith provided a detailed description and the results of the implementation of ALM in the pre-calculus classes at University of Nebraska – Lincoln (UNL). Active learning has become well established at UNL, and the math department will extend this work to Calculus I and II classes during 2016-17. Recently they received an NSF grant to study mathematics department transformation using NICs as a lens.

Using the $MCOP^2$ as the Primary Observation Protocol for Assessing Teacher Candidates in Methods Courses and Student Teaching Practica by Zelkowski and Gleason describes the process used at their institution to move from a general observation protocol (used for all subjects) to using $MCOP^2$ for their mathematics teacher candidates. He reports that $MCOP^2$ provided a consistent rating with the other general observation tool used in their program.

Clinical experiences (including support for mentor teachers)

Biagetti & Oloff-Lewis investigated the *Variability in Clinical Experiences across the California State Universities* (CSUs). They report the similarities and differences of mathematics teacher preparation programs among 18 CSU campuses. They learned of surprisingly high variability across the campuses. For example, the number of times teacher candidates were observed during their first semester varied from one to ten times. They identified these great variations in program practices pose challenges to measurement efforts as well as transfer of effective practices, not only among the CSUS, but likely across the MTE-Partnership.

Brosnan & Sears report on their PDSA cycles for their Co-Planning and Co-Teaching SubRAC. Specifically, they investigate the ways in which co-planning and co-teaching strategies assist the mentor teachers and teacher candidates to focus their work on students' learning of mathematics? In addition to positive results beyond what was expected, they found that the structures of improvement science helped them engage in research with their partners as part of their efforts to transform the field experiences of their candidates.

A third report regarding clinical experiences, by Cayton and Grady, shared strategies to support co-teaching endeavors in their clinical experiences. In this context co-teaching is shared teaching between mentor teacher and student teacher. They used PDSA cycles to implement and study these co-teaching strategies. Their data collection tools include pre-surveys, a co-teaching observation protocol, a survey of strategies used, just in time surveys, and exit surveys. Preliminary results show that clinical teachers and interns reported the benefits of the co-teaching strategies.

Recruitment and retention of teacher candidates

Martinez, Taylor, and Amick report the results of a survey of mathematics teachers in a teacher preparation program or serving in their first three years of teaching regarding how early career teachers are being supported. This preliminary data collection effort serves to launch the work of the newly emerging STRIDES RAC, results of which were analyzed at the conference and used to inform next steps for the community.

Ordorica reported on her recruiting efforts at CSU Chico, and in particular how she drew upon the recruiting modules of the MATH RAC. She concludes that the Implementation Guide produced by the MATH RAC provided the infrastructure to make recruitment tasks feel more manageable and also provided a system for tracking the efforts. Whitfield also was concerned with recruitment issues, curious to understand decisions to teach—especially with regards to the impact of competitive scholarships the are used to draw in mathematics teachers. She learned that many students who had obtained a Noyce scholarship made their decision to teach far earlier than others, while non-scholars were more influenced by external factors. Whitfield's survey study provided some insights on recruitment factors that differed between Noyce and non-Noyce scholars.

Summary

The MTE-Partnership has taken the time (five years) for participants to select, study, and own problems as described in Gomez, Russell, Bryk, LeMahieu, and Mejia (2016). At this fifth conference RACs were able to offer more complete ideas and more fully validated materials. Most RAC materials have been tested and validated at multiple sites and these products remain available for other partnerships.

RACs have been able to create useful strategies and materials by targeting specific challenges in the preparation of secondary mathematics teachers. The new challenge facing partnerships is to refocus attention on the change efforts of program transformation. Not only to re-engage the many different constituents involved in secondary mathematics teacher preparation, but more immediately determining which materials, from which RACs, should they incorporate in their programs. Partnership teams reported that part of the problem is finding additional participants in their local groups to assume leadership roles with respect to incorporating new RAC ideas and materials in their programs. Although much has been done, more effort is needed and it is needed faster.

The elements of these proceedings of the Fifth Annual Mathematics Teacher Education Partnership document the maturation of the research communities and the implementation of the NIC research design overall. This maturation has made apparent the need to return to the larger goal of program transformation toward the "gold standard" identified in the community's guiding principles (Mathematics Teacher Education Partnership, 2012). Further, elements of program transformation that are present in the guiding Principles that are not explicit being addressed by a RAC or in the present RACs are becoming apparent, such as the complex challenges of equity and social justice. The opportunity to return to these broader issues at the conference has re-energized and the joint purpose and identity across the partnership. We believe you will find evidence in the proceedings that follow that the four goals of the conference were successfully achieved.

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OPENING ADDRESS

Keeping the Course: Transforming Mathematics Teacher Preparation in Responsive, Responsible Ways

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Efforts to improve teacher education programs to ensure that they have the knowledge and skills to be successful in today's schools is complicated not only by the layers of scrutiny by a wide variety of stakeholders such as: government agencies, private organizations, politicians, and individual citizens, but also with the myth that teaching ability is an innate gift. Attempts to ensure that every teacher can teach are hobbled by this myth that teachers are born, not made. For example, actions taken in respond to government policies reflect this myth when the policy focus is on raising teaching standards, but the actions mutate into efforts to recruit high-flying graduates to the profession and encourage 'bad' teachers to leave. Rarely do such policies emphasize providing the structural and financial supports that teachers need within the context of where they work.

Teacher preparation is a sprawling enterprise, and has only grown larger and more diverse. The emergence of a variety of certification paths has increased the complexity and inconsistency of how teachers enter the classrooms. Within this environment, a long list of criticisms of teacher preparation appear in the public discussions about teacher preparation, including:

- Divide between theory and practice
- Teacher preparation courses are anti-intellectual (Mickey Mouse courses)
- Unnecessary barriers
- Not enough teachers of color
- Not enough intellectually elite teachers
- Not enough content knowledge
- Not enough clinical experience
- Not enough attention to issues of equity and social justice

These criticisms may be legitimate for some parts of that landscape; however, hyperbole, oversimplification, and overgeneralization are rampant. Nevertheless, this

[1] Ronau contributed to this paper while serving at the National Science Foundation. The comments expressed here are those of the author and do not necessarily reflect the views of the National Science Foundation.

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seemingly constant din contains real messages about improving teacher education. We must find effective ways to be responsive to these calls for change. How should we move forward amid this storm of negative discourse and calls for change? Which issues should we prioritize? Which audiences should we address?

These questions are particularly important to this group, the Mathematics Teacher Education Partnership (MTE-P) because of its overarching goal: *To **transform** secondary mathematics teacher preparation in order to ensure an adequate supply of new teacher candidates prepared to support their students' college- and career-readiness*. MTE-P recognized the national need for more and better mathematics teachers and initiated efforts to address that need.

Before attempting to answer the questions above, we should recognize some additional realities associated with changing educational practice in classrooms. Changing teaching practice is expensive; sometimes in terms of dollars, sometimes in terms of time commitment for preservice and inservice teachers, and sometimes in terms of student opportunities to learn. We must use these resources wisely by focusing on effective strategies for change. Thus, we need to find, develop, and use research-based ways to support preservice and inservice teachers. In short, theory is important, research is critical.

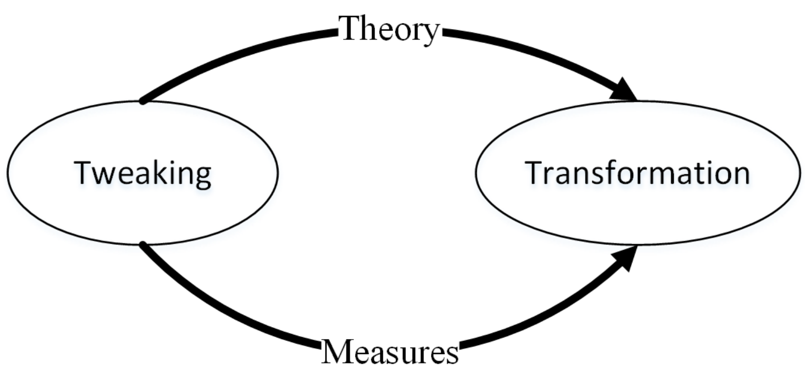

Figure 1. A Model to Support Consistent, Continuous Classroom Change

We also need instruments that address meaningful and agreed-upon outcomes before changes to educational preservice and inservice programs are launched. Finally, the process of transforming classrooms needs to take place in ways that are as least disruptive to the educational enterprise as possible. We can do this by taking small steps and producing incremental, but consistent change. Figure 1 shows one way to think about this idea. Innovation in classrooms should only be attempted with theoretical support and with measures that will demonstrate differences in the desired outcome. The point is to make small changes, tweaks, consistent and continuous over time, which allows for midcourse corrections and provides real change in the context of the work. In this way, we can approach classroom change responsibly with teachers as active leaders in the research.

Given this background, she returned to the two puzzles suggested earlier:

Puzzle 1: When and how to respond to criticism/new ideas?

Puzzle 2: What kind of evidence, arguments, and warrants do we need to muster?

Puzzle 1: When and how to respond to criticism/new ideas?

Teacher preparation programs have been criticized for lack of rigor, low productivity, lack of diversity, and as ineffective for preparing candidates to do the job of teaching. Few disagree that preservice teachers need robust and quality clinical practice, coursework, content knowledge for teaching, and knowledge and skills for culturally responsive/relevant teaching and to implement high leverage practices. On the other hand, many of these criticisms are based on anecdotal data, which works well for stirring up public sentiment but often fails to identify true challenges. To make progress in improving teacher education programs we need valid and reliable measures of mathematics teaching effectiveness and ways to implement those measures consistently and ubiquitously for comparisons within and across multiple groups. Otherwise we stumble blindly in our attempts at teacher education improvement as we react to symptoms not causes; exasperating the lives of the educators caught in the mix.

Recent research can provide help in instructional improvement, and to guide how to respond to such criticisms, over time, in responsible ways. Wilson drew from experiences with programs such as: Comprehensive School Reform, Chicago School Reform, The Silicon Valley Mathematics Initiative (SVMI), Long Beach Teacher Prep Alliance, and Reading First. Teacher education programs that seem to be successful use metrics specific to the context, such as: diversity of candidate pool, location of graduates across the state/country, retention rates, diversity of students taught by graduates, measures of content knowledge for teaching, progress charts on mastering high leverage practices, principal or supervising teacher ratings, and perseverance. From these research activities, we've compiled a list of effective strategies for instructional improvement:

- Mobilize and sustain support: Strong support matters. the absence of will leads to withering of reforms;
- Identify and deploy a set of policy instruments/institutions: Coordinated policy instruments matter;
- Implementation requires the balance of capability building and accountability;
- Provide teachers/teacher educators with opportunities to develop adaptive expertise: Policies must motivate and engage teachers while also building capability;
- Build and enable cultural and community support: Policy implementation depends on social relations among teacher educators, teachers, schools, state departments, and communities; and

- Produce outcomes with demonstrable effects: Persuasive demonstrated effects are needed for both teachers and other groups essential to policy implementation.
- p.s. None of this happens without relational trust….

Puzzle 2: What kind of evidence, arguments, and warrants do we need to muster?

We need valid and reliable sources of evidence/warrants/arguments for individual candidates as well as for our programs. We need to develop a database, an infrastructure, and a culture to manage, share, and interpret that data. We also need to identify those issues are about values and are not about evidence. Evidence is important when entering the public discussion, but evidence is not ALL important. We also need stories. We must learn to persuade with data, stories, trust, and engagement with stakeholders. Finally, we should collaborate with others by sharing activities, measures, results, and data within and across educational institutions. We cannot change what we cannot measure, but our measures results are more valid and convincing if they span multiple populations and contexts. In research, (sample) size matters.

One way to engage stakeholders is through the development of strategies to present complex and numerous data (and stories) in attractive and understandable ways, that demonstrate our journey towards teacher preparation improvement. We must be clear about our approach to improvement by sharing our model of small, research-based, well-documented, teacher-led, reliably-measured trials in classrooms.

We need common metrics for teacher education programs that specifically address the concerns of the stakeholders such as: diversity of candidate pool, location of graduates across the state/country, retention rates, diversity of students taught by graduates, measures of content knowledge for teaching, progress charts on mastering high leverage practices, principal or supervising teacher ratings, and perseverance.

Putting it all together

If we are to keeping the course, that is transform mathematics teacher preparation in responsive, responsible ways in the current turbulent environment, we must be transparent, systematic, and persistent in our efforts. As a community, we must agree on a vision that is neither too narrow nor too rigid, but nonetheless focused, democratically robust, mathematically-sound, and ambitious (both in terms of the mathematics and reaching the needs of all students). We also must understand that enabling that vision will take long-term, collective work in protected space with adequate resources (including time and trust). We need to take lessons from the past both within teacher education and more generally in education reform. We must address teacher educator capacity, will, and energy to develop, guide, and evaluate improvement-based programs. Infrastructure that enables the use of varied expertise and engagement, and a culture of trust and critique must be built and nurtured. Mathematics teacher education programs need ways to gather information that allow for accurate accounts of progress and problems, including robust assessments that provide helpful information about both what students understand and what teachers do.

To approach teacher education in this way we need to:

- Conceptualize reforms as experiments that need sound research that unfolds over time and goes hand-in-hand with classroom practice,
- Create norms and values that embrace “steady work,”
- Invest in the development of social trust,
- Maintain the will and focus in a noisy, conflict-full environment,
- Include the broadest set of critical stakeholders possible,
- Invest in the development of a broad set of indicators that speak to multiple stakeholders.

MTE-P has a good start in this process as we are working toward a common vision for mathematics teacher preparation that spans 101 universities and 142 K-12 schools and districts across 30 states. Now in its fifth year, the community has learned to work together, to persist in this process, to look past the noise as we develop meaningful measures, and to continue to build partnerships and recruit collaborators. There is much at stake in the current politically charged environment in which we engage in mathematics teacher preparation. As educators, we can no longer work alone in our local district or community to create the impact needed for meaningful change. We must work together to pool our efforts and magnify our results. MTE-P is a good start for this endeavor.

Panel Talks

Pre-Session on Equity and Social Justice

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One goal of the Fifth Annual Mathematics Teacher Educators Partnership Conference was to, "make equity and social justice more explicit as an essential component of the partnership aim." On the first evening of the conference, a loosely structured gathering was organized to discuss the role of equity and social justice in the MTE-P work. To gain a perspective as to how MTE-P has focused on the issues, participants examined the Mathematics Teacher Education Partnership (2012), which includes several statements that indirectly support equity issues such as access and achievement. Two of the principles speak more directly to these issues. First, Guiding Principle 5: Candidates' Knowledge and Use of Educational Practices, Section E calls for Attention to Diversity:

> The teacher preparation program ensures that teacher candidates recognize that all students in their classes—including low-performing students; gifted students; students of different racial, ethnic, sociolinguistic, and socio-economic backgrounds; English language learners; students with different sexual orientations; and students with disabilities—have the potential to make important contributions, and that they maintain high expectations for all students.

Secondly, Guiding Principle 6: Professionalism, Advocacy, and Leadership calls for teacher preparation programs to ensure future teachers hold themselves and colleagues responsible for the mathematical success of all students. In particular, Section C: Sense of Justice states:

> The teacher preparation program fosters a sense of agency in its teacher candidates so that through their actions, behaviors, and advocacy, candidates demonstrate a dedication to equitable pedagogy that promotes democratic principles by holding high expectations for all students, while recognizing and honoring their diversity.

The interests underlying the call for the MTE-P Equity and Social Justice working group was to consider if these two guiding principles were sufficient to guide efforts on this topic for the MTE-P project, and also to initiate discussions regarding the breadth of issues related to equity and social justice to be considered in relation to secondary mathematics teacher preparation.

From 6:30 to 7:15 PM on the first night of the conference, approximately 50 MTE-P members, slightly over half of those attending the conference, sat in small groups at tables while Drs. Lawler and Strutchens led the discussion. To prepare for this

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conference pre-session, each RAC was charged to identify ways their work addressed issues of equity and social justice, or incorporated specific MTE-P Guiding Principles. The RACs presented their reports during this opening pre-session. Their reports are included in the appendix of this paper.

The work sessions attendees were asked to brainstorm additional issues related to equity and social justice that are important for the preparation of secondary mathematics teachers. Rich, intense conversations were held at each table and a few of the ideas generated in those discussions were reported to the full group. Group responses were organized into categories: children's mathematical identities, mathematics teachers' identities, biases and stereotypes in the discourse about people and mathematics, biases in the structures around mathematics education, and challenges to recruitment. Participant responses shared that illustrate each of these categories appear in Table 1.

Table 1
Responses to table discussions about issues related to equity and social justice that are important for the preparation of secondary mathematics teachers.

Category with responses from the working group
Children's mathematical identities
Mathematical identity (e.g. *Do children see themselves in curriculum?)*
What teacher actions cause positive or negative mathematics identities?
Better ways to assess mathematical potential, such as in early college experience
Mathematics teacher identities
Teaching mathematics is a sociopolitical act
Empower candidates to be agents of change
Maintain candidates' confidence in mathematical abilities as they take higher mathematics
Biases in the discourse about people and mathematics
Discourse (how people interact and the expectations they have for one another)
Preservice teacher awareness of deficit language, discourses, and practices
Deficit language among ourselves as Mathematics Teacher Educators (MTE)
MTE biases and beliefs, such as how we perceive students, or who should have access
Stereotype threat, for both faculty and preservice teachers
Biases in the structures around mathematics education
Tracking
Integration of diversity, equity, and social justice specifically to mathematics and specific domains
Institutional racism
Challenges to recruitment
Discouraging messages against becoming a teacher
Clinical experiences could attend to equity and social justice with equal importance to mathematics instruction
Structural challenges to recruitment that eliminate potentially good candidates, such as advising and some standardized tests (related to cultural capital)
Broadened participation to match local population (maybe recruiting earlier can help)

Table discussion groups were also asked to consider what sorts of actions might MTE-P take to address the direct and indirect challenges of equity and social justice. One topic frequently mentioned was the need for professional development (PD) within the MTE-P community; many of the participants indicated that they felt inadequately prepared to achieve goals related to equity and social justice as set forth in the Guiding Principles. Subsequent discussion on PD revealed that structures like a webinar would be insufficient for the complexity of the issues, for example the possible need to visit beliefs or values. One idea emerged recommending the development of modules including talking points for sharing with colleagues at our home institutions, as well as with district partners. Another suggestion called for the development of specific activities that could be used not only with preservice mathematics teachers, but also with other members of our local teams. Additional discussion centered on how MTE-P might provide a support system for the efforts on individual RACs to incorporate equity and social justice into their work.

A second element of this discussion was focused more on the content of potential support systems and PD. One suggestion promoted increasing awareness of how privilege works, and to identify the variety of ways people are privileged in this society. The Harvard Project Implicit (implicit.harvard.edu/implicit/index.jsp) was identified as a specific example that can help an individual identify his or her biases. Dr. Karen King cautioned this effort, pointing to a body of research that has demonstrated that often in an attempt to teach diversity class, people come away with previous beliefs and biases hardened. Thus, it is important that we examine professional development programs around equity and social justice issues well before we implement them within the partnership.

As the working group wrapped up, several participants suggested that MTE-P might support an Equity and Social Justice Working Group. Dr. King raised challenges to keep in mind as the group moved toward planning activities. For example, she reminded the group that equity, diversity, and social justice are not the same things and that the terms often get used interchangeably. To prevent confusion about these terms in the group's activities, she advised to first tease out distinction for each. Dr. King posed a question that speaks to the nuances of the terms, recognizing that our educational system is more segregated now (Rothstein, 2013) than at the time of Brown vs. Board of Education: *Can schooling be separate and equitable?* Dr. King also cautioned against the draw to essentialize children (and people) due to membership of a particular group. Another common issue related to equity and social justice in mathematics education is that a task on its own does not make for equity, but also the enactment—the teaching—of that task is critical to how it is perceived by learners. Her final advice was to study research outside mathematics education to more fully understand these challenges. For example, there is a considerable literature on how diversity training is often ineffective. Similarly, there is robust literature in the business community about recruitment, especially related to recruiting people for something they may not know they want to do--such as become a high school mathematics teacher.

Dr. Gary Martin reiterated that challenge for us, members of MTE-P, to consider and learn how we can educate ourselves and our institutions. Specifically, what might or should our teacher education programs do to develop skills, knowledge, and dispositions aligned with the charges of equity and social justice; what is it we hope our preservice teachers will leave us prepared to do as high school mathematics teachers. Dr. Marilyn Strutchens challenged us more broadly to consider how to we raise consciousness in the community of the complexity of these challenges. How can we create change agents? And how can MTE-P leverage its role to make change?

The Equity and Social Justice work session concluded with a very strong expression of interest to create some structure within MTE-P to pursue these challenges. As complex as these issues are, they are certainly core to preparing high school mathematics teachers. A first step may be to heighten the recognition that these issues are core to the work of mathematics education.

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Appendix: RAC Reports on Connections to Equity & Social Justice

Active Learning Mathematics—ALM

- ALM in undergraduate mathematics contributes to improved engagement, access and success of all students (e.g. Freeman et al., Laursen et al., etc.)
- Explicit attention being given to problematic features of instruction in undergraduate mathematics that have been institutionalized in departments & university
- Student Engagement in Mathematics through an Institutional Network for Active Learning (SEMINAL): Explicit focus on characteristics of productive math departments and studying the process of institutional change

Clinical Practices

- One of the primary drivers of the RAC is: Focus on access and equity
- Organize mentor selection and support around deepening expertise with math content, math standards, MTPs, and mentoring strategies
- The preparation of each new teacher of secondary mathematics represents an opportunity to disrupt long-standing teaching practices that contribute to inequities in learning outcomes.
- Ensure that requirements for student teaching and feedback during student teaching emphasize the responsibility of TCs to advance mathematics learning among secondary students through collaboration with more expert mentors in use of MTPs.
- Ensure mutual agreement between district(s) and university about what quality teaching of secondary mathematics looks like and how to further skills of all teachers (including TCs) and see mentor teaching as part of career ladder.
- Use the NCTM *Principles to Actions* eight core teaching practices to promote deep learning of mathematics

- *Change Ideas (How)*
    - The development of a PD program related to mentoring mathematics teachers
    - Provide ongoing PD and course work related to the Common Core State Standards and NCTM's Mathematics Teaching Practices
    - Convene either face-to-face or online meetings to plan field experiences, articulate expectations, and reflect on norms and cultures within the class settings.

MODULE(S^2)

- Provide representations of teaching practice and teaching scenarios which incorporate research-based knowledge about culturally and mathematically diverse students' learning and their conceptions of the specific content topics.
- Include historical notes which include contributions of all peoples to the development of mathematical ideas
- Develop Preservice Mathematics Teachers' professional noticing skills

Marketing to Attract Teacher Hopefuls—MATH

- *Past activity:* Implicit strategies to target underrepresented populations
- *Possible directions:* More overt, direct, and targeted strategies tied to local communities and institution to increase number so under represented populations

A Deeper Dive into Plan-Do-Study-Act Cycles and Measures

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This talk explores more deeply the structures and measures of the Plan-Do-Study-Act (PDSA), a core principle of improvement science. We began this discussion with the challenges that we faced in moving from a traditional research paradigm to using improvement science, specifically the struggles we experienced in terms of starting small with the goal to ramp up rapidly. Lewis (2015) sums up the transitions that we had to make:

> Improvement science… treats variation in implementation and setting as important sources of information and provides tools to grasp and learn from variation (in both positive and negative directions) in order to redesign both the intervention and the system. (p. 55)

And,

> Improvement science assumes scale-up occurs through integration of basic knowledge with the "system of profound knowledge," such as knowledge about how to build shared ownership of improvement, to detect and learn from variations in practice, to build and share knowledge among practitioners, to motivate frontline innovators, and so forth. (p. 55)

The PDSA cycle (Lewis, 2015), Figure 1, is an essential tool of improvement science,

> a process for rapid cycles of learning from practice, coupled with three fundamental questions that drive improvement work: (1) What are we trying to accomplish? (2) How will we know that a change is an improvement? and (3) What change can we make that will result in improvement? (pp. 54-55)

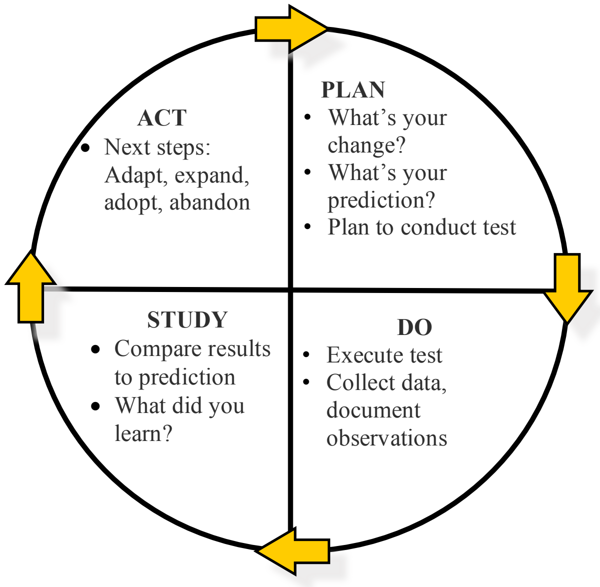

Figure 1. Plan-Do-Study-Act model.

In the "Plan" stage we articulate the change we intend to implement and record predictions about what we expect will happen. As, "Do' suggests, in this stage, we attempt the change and document what happens. The "Study" stage is where we compare the actual results to the predictions we made. Next, we "Act", deciding what to do next. Do we adapt, adopt, expand, or abandon the change idea? In improvement science PDSAs are used (Kawar, Mejia, Bennett, & Dolle, 2015) as

- the key mechanism by which we learn,
- a way to test and revise theories at an appropriate scale,
- a way to gain information by doing SOMETHING (even if it's small) rather than obsessing over getting it "right" from the start,
- a common approach that disciplines our efforts so we are efficient.

The predictions made in the Plan phase make explicit our understanding of the system we are working within and how we think our change idea will impact that system. The gap between our predictions and the actual results is where our learning happens. When what we predict comes true, we only have confirmation—suggesting that there is no gap in our understanding of how our system operates. If we are unable to explain why a test succeeded, then we may still have a gap in our knowledge, and we may wish to repeat the test to solidify our understanding of the system. When our predictions are wrong, we have exposed a gap in our knowledge providing an opportunity and a target to dig in to understand more about why things are the way they are.

The change ideas to be examined in PDSA cycles are taken from the driver diagram. The driver diagram is developed by establishing a clear aim, a specific statement of what we are trying to accomplish, and identifying primary drivers or factors which directly impact the aim. The change ideas are the actions identified as appropriate for affecting the primary drivers so that we move closer to our aim (Bryk et al., 2015). Whether or not our change is actually an improvement is determined by collecting and analyzing data.

This approach is different from the traditional approach often taken in education reform. The traditional approach involves choosing a change idea to implement, delaying implementation until the idea has been "perfected," and then enacting the idea system-wide. When the change does not improve the system we have often done more harm than good to the whole system and have missed the opportunity to gain a deeper understanding of our system and the change idea from the failure (Kawar et al., 2015). Improvement science implies that testing change ideas should start small and slowly expand to learn along the way. Consequently, when we fully implement a change idea, we have gathered knowledge about not just the effectiveness of the change but also how to get the change to happen in various contexts.

In initial PDSA cycles the purpose is to determine how to get the change idea to work. The next cycles focus on learning how to get the change to work across multiple contexts and determining the support process needed to enact the change system wide. Finally, the change idea is integrated into the system (Kawar et al., 2015). Although, this process may seem long to address one small change, particularly in a complex system, PDSAs are focused cycles designed to move through the testing of change ideas relatively quickly. Moreover, PDSAs can be run in parallel so several changes can be tested on different parts of our driver diagram at the same time.

The scale at which we choose to test a change idea depends on several factors: (1) How confident are we that the change idea will lead to improvement?; (2) What is the cost of failure?; and (3) How resistant to change is our system? Low confidence in the change, with a high cost of failure and a system resistant to change suggests that we run a very small scale test. Whereas, a large-scale test might be appropriate when there is high confidence in the change, a low cost of failure and a system indifferent to change (Kawar et al., 2015). As we progress through PDSA cycles confidence in the change idea grows and the cost of failure decreases, consequently our system becomes more ready for change and we can implement the idea system wide.

PDSA FORM WITH PROMPTS

Test Title:				**Date:**	
Tester:		**Cycle#:**		**Driver:**	
What change idea is being tested?					
What is the goal of the test?*					

*Identify your overall goal: To make something work better? Learn now a new innovation works? Learn how to text in a new context? Learn how to spread or implement?

1. PLAN				**3. STUDY**
Questions: Questions you have about what will happen. What do you want to learn?	**Predictions:** Make a prediction for each question. Not optional.	**Data:** Data you'll collect to test predictions		**What were the results?** Comment on your predictions in the rows below.
			→	
			→	
			→	
			→	
Details: Describe the who/what/when/where of the test. Include your data collection plan.				**What did you learn?**

2. DO (Briefly describe what happened during the test, surprises, difficulty getting data, obstacles, successes, etc.)	**4. ACT** (Describe modifications and/or decisions for the next cycle; what will you do next?)

Figure 2. PDSA Form with Prompts. By Lawrence Morales and Alicia Grunow, ©2016 by the Carnegie Foundation for the Advancement of Teaching. Licensed for public use under the Creative Commons license CC-BY-NC-SA 2.0.

The PDSA form, Figure 2, provided to us by the Carnegie Foundation, is an effective tool for keeping a record of our progression through the testing process. Completion of the form focuses our thinking. We are reminded how the planned cycle fits into our overall driver diagram, our PDSA steps are clearly outlined, and a concise record of the results are available as the next cycle is planned.

Measures

Ideally, data should only be garnered for a clear purpose. Data can be used for accountability, research, and improvement (Bryk et al., 2015). If used for accountability, the data is examined to identify problematic or exceptional performers, with the possibility that the outcome may result in problematic performers being terminated. When data is used for research, theories are developed and relationships among variables may also be examined. Data used for improvement purposes seek to develop as well as evaluate change in practices, with the outcomes of data documenting the nature of change and relevant processes. As a network improvement community, the Clinical Experience RAC used data to improve clinical experiences to place a greater focus on the mathematics teaching practices (NCTM, 2014)

The Clinical Experience RAC of the Mathematics Teacher Education Partnership (MTE-P) uses a balanced set of measures, namely: outcome measures, process measures, and balancing measures, consistent with improvement science (Bryk et al., 2015; Lewis, 2015). Outcome measures consider how the system performs, and the overall result. Process measures evaluate whether the various parts of the system are performing as anticipated, and the balancing measures monitor adverse effects to other parts of the system as change is implemented. On a driver diagram, the outcome measures, which are often lagging indicators, provide insight into the extent the aim statement is achieved; the process measures examine secondary drivers, which are early indicators as to whether the proposed change is improving the system; and the balancing measures consider items that are not identified as primary or secondary drivers for the diagram to ensure the change is not resulting in unintended consequences. Using a balanced set of measures provides a holistic view of the implementation and sustainability of a change idea.

Clinical Experiences Research Action Cluster's (CERAC) Measures

The Clinical Experiences RAC is sub-divided into three groups: pair-placement, methods, and co-planning and co-teaching (CPCT). In the pair placement group, two teacher candidates are paired with one mentor teacher during the student teaching experience. The methods group focuses on preparing teacher candidates while they are enrolled in the mathematics education methods course, and the CPCT group encourages the teacher candidate and mentor teacher to teach lessons together. The aim statement for the RAC indicates teacher candidates should use the NCTM (2014) eight teaching practices at least once a week for the duration of their field experiences. The secondary drivers indicate that there is a need to: increase the amount of mentor teachers who are informed of national standards and current reform initiatives; attend to the teaching practices within methods courses; encourage teacher candidates to engage in self-assessment and reflect on the extent their enacted lesson embodies the teaching practices; facilitate collaborative meetings to discuss beliefs, complexities and challenges; and develop infrastructures to support teacher candidates' needs.

Common instruments (*MCOP^2*, *Mathematics Teaching Practices Survey*, and the *MTE-P Completer Survey*) are used across the three groups within the RAC to gather data for the outcome measures. The MCOP^2 measures K-12 classrooms instructional practices' alignment with national standards documents (Gleason, Livers, & Zelkowski, 2015). The Mathematics Teaching Practices Survey is a checklist tool used to identify whether any of the NCTM (2014) eight standards are addressed by teacher candidates during each day of their field experiences. The MTE-P Completer Survey asks teacher candidates to share their perspectives about the extent their teacher education program prepared them to be effective teachers. Therefore, the instruments are used explicitly to gather data to determine whether teacher candidates are taught to use the mathematics teaching practices in their teacher education program, and the extent to which they actually use the practices.

Each group within the RAC created focused instruments to align with the group objectives and to gain insight into the process measures. For example, the methods group created modules about the teaching practices and assesses the extent to which teacher candidates deemed the modules to be effective. The methods group also uses pre- and post-methods-course questionnaires. The data garnered provide insight into the nature of the methods course and the extent it prepares teacher candidates to address national standards. Similarly, the paired placement Sub-RAC uses surveys (of the mentor teacher and university supervisor) and focus groups to monitor the complexities of the field experiences and to refine the infrastructure. The CPCT group uses professional development, just-in-time, and exit surveys to monitor the extent to which teacher candidates and mentors are informed about the national standards and CPCT, to gain insight into personal reflections and self-assessments, and to learn about the nature of the clinical experiences. Hence, the process measures provide actionable data that can be used to reduce the likelihood that the change efforts are cultivating unintended negative results.

To gather balancing measures faculty members are encouraged to converse with mentor teachers, teacher candidates and supervisors, to discuss other variables that are also being affected due to the implementation of change ideas related to clinical experiences. Considering that time is valuable, and can have implications on how a reform idea is introduced and sustained, our balancing measures focus on out-of-class planning time. To garner these data, a weekly online survey could be sent to all concerned parties that asks about the amount of out-of-class time being used to prepare for enacted lessons.

Employing a balanced set of measures provides insight into the extent the clinical experiences RAC's overall goal was achieved, and whether the changes examined through PDSA cycles are having desirable effects. Considering that improvement science relies on PDSA cycles as a systematic process to gather data, changes can be made to the idea during iterations of the PDSA cycles to ensure the overall system is improved. Well-crafted measures and thoughtful implementation of PDSA cycles allow for the robust research design of improvement science to embrace variation in implementation and setting as important sources of information, and to learn from this variation to improve both the interventions and hopefully the system.

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Pathways to Program Improvement

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If you think transformation is linear, you'll live to be disappointed. – Gary Martin

Members of the Mathematics Teacher Education Partnership (MTE-P) who have begun work on the complex challenge of program transformation were invited to share their experiences around these efforts. This panel gets to the heart of MTE-P. At its inception, MTE-P always had a transformation goal – increase the supply of secondary mathematics teachers as well as the quality of both our programs and the future teachers we produce. The Research Action Clusters (RACs) were meant to help with that work. But in order to truly transform, each program must draw upon the work of multiple RACs together and integrate what is learned from the RACs into our programs. Enduring and meaningful change is often slow change. Who's available to do the work? What's the priority for improvement? What kind of institutional support do we have?

Now that the RACs have established a foundation, MTE-P is ready to address what it means to transform. What does transformation look like? MTE-P's proposed strategy is to support teams as they create strategic pathways for their local programs. No one model will work for everyone, but might a framework be created with the flexibility to be useful in diverse local contexts? MTE-P is committed to building the capacity and infrastructure needed to help partnerships transform and improve their programs. This panel sets up the work of a new working group – Transformations – and establishes a foundation for their work. The panelists were asked to address the following questions:

- What is the status of your team with respect to overall transformation of secondary mathematics teacher preparation?

- Where are the opportunities for making progress towards that goal?
- What are the challenges in making progress towards that goal?
- What might MTE-P do to support your progress?

The responses of each panelist to these questions follows below, with concluding statements from the Reactant, Robin Hill.

Mark Ellis – California State University Fullerton

California State University at Fullerton (CSUF) is part of the 22-campus teacher preparation network of the CSU system, which also comprises the CSU MTE-P team. CSUF has a rich local context within the partnership. The local work they've done has helped in a bidirectional sense – they have been able to secure additional funding and then use that funding (e.g., Bechtel Foundation) to develop more partnerships and collaborations. Through this work, they have been able to envision teacher preparation development as a continuum over time instead of isolated incidences of learning. Through the Bechtel grant, CSUF developed a shared vision within their own institution and in partnership with two local school districts. That development of a shared vision allowed for more explicit conversations across the local partnership, especially focused on what does a well-prepared teacher look like and how can that be supported so that learning for *all* K12 students can be supported.

During this time, the campus was bringing in new mathematics education faculty within the Colleges of Natural Sciences & Mathematics and Education. The new faculty were easily able to talk about elements of the transformed mathematics teacher preparation program (e.g., co-plan/co-teach); they became "normalized" conversations. The modes of collaboration and conversations were the norm among the new faculty, experienced mathematicians and mathematics educators, and school district partners. Having new Deans in both colleges at the start of the 2016-17 academic year aided in solidifying the program transformation as they understood the transformed program as something that was typical.

One set of challenges everyone has faced involves time: the time for planning; the time for implementing; the time for collecting data about the implementation; and the analysis of the data and revisions to that the model. For example, Plan-Do-Study-Act cycles take time. Another challenge was the time required for long-time faculty to embrace the transformed program as the new normal.

Having the support of the statewide network of the 22-campus CSU team has helped address the challenge of time, through persistence and visibility. The CSU system is now a go-to partner across the state because of their involvement in MTE-P. In fact, they were successful in advocating the addition of 16 mathematics-specific items to a statewide teacher exit survey that will allow faculty to look deeper into their programs using data both locally and across institutions.

Much can be learned from not only the work at CSUF, but also across the CSU team. California is an exceptionally diverse state, so context is especially important and matters. Among the insights gained from conversations across the 22-campus network was the realization that some campus credential programs did not require content specialists to do supervision of teacher candidates. When this surfaced in survey generated by the CSU MTE-P team, it provided faculty with substantive data to bring to local campus administrators to advocate for program changes. Collectively, it's essential that program quality should not be affected by different contexts.

Margaret Mohr-Schroeder – University of Kentucky

The current status of teacher preparation in the Commonwealth of Kentucky is a little chaotic and unstable. There is a dire need for middle and secondary mathematics teachers across the Commonwealth; both the urban and rural regions are struggling to get qualified teachers into classrooms and staying in those classrooms. Even alternative certification programs such as Teach for America have not solved these two issues of recruitment and retention of mathematics teachers. As a result, mathematics educators from across the Commonwealth have come together, on their own accord, to discuss how to collectively solve the challenges facing mathematics teacher preparation. One key challenge is that there is little state support for thinking about teacher preparation differently; for looking at teacher credentialing differently.

Recruitment into teacher preparation programs remains a fundamental issue, especially because the high school graduating population is decreasing across the state. A majority of the public institutions have had to recruit students from out of state, which poses different recruiting challenges than from within the state. Many of the programs have undergone radical transformation over the past five years. For example, Western Kentucky University and Morehead State University are official UTeach replication sites. University of Louisville and the University of Kentucky both added undergraduate certification programs when their 5th year/MAT programs began to struggle with numbers.

The Commonwealth also has a dramatically changing policy landscape. While the new governor is promoting STEM, the promotion is at the community college level. Meanwhile, there have been deep cuts, including mid-year cuts, to institutes of higher education. Furthermore, pending litigation regarding many education-related issues and the promotion of private education over public education make transformation difficult and tumultuous.

The retention of teachers, not just in the first five years, but especially between years 10 – 15 is an unprecedented problem. Experienced teachers are leaving the classroom because their job has become unfulfilling. As they leave public education, they seek out different ways to reach people; they still wish make an impact. One example is the loss of teachers to manufacturing companies. These companies realize the great knowledge and pedagogical skills of secondary mathematics teachers, so they recruit and entice teachers to leave the profession to come and deliver professional development to their workers. They offer higher salaries, a more flexible work schedule, benefits even if you work part time, and all the resources and tools they need to deliver the training to the adult learners.

Yet the biggest challenge in Kentucky is that teachers are seen as a problem in the state.

Despite the challenges in education facing Kentucky, there have been ample opportunities for transformation and impact, many of which are due to the MTE-P. The current focus on the MATH and STRIDES RACs are important. Although many Kentucky mathematics teacher preparation programs have transformed programs, they now need to attract more students and must focus on specific induction structures to retain them after they've graduated.

Specifically, at the University of Kentucky (UK), there has been institutional transformation. Through the involvement in Science and Mathematics Teacher Imperative (SMTI) and MTE-P and going through the SMTI analytical framework, UK identified the need to create a STEM niche. So, they created a Department of STEM Education which helped to pave the way for the new undergraduate program in which a student earns a double major in STEM education and mathematics (or whatever content area they will be teaching).

Through this transformation, UK learned that institutional transformation evolves slowly and is hard work. Partnerships must take a deep look at their programs and institution and often throw out preconceived notions of what something should look like or how it should function. But looking at things this way is how you can dramatically change what you're doing.

Moving forward, the broader STEM community in Kentucky is working on developing a statewide STEM education center. Although transformations are happening across the state, there is no backbone structure to help pull it together. A center would help to scale transformations across institutions, leverage resources, collect and analyze common data, and generally just help support each other as change agents.

There are many challenges in Kentucky moving forward. Being a highly-regulated state in terms of teacher preparation is one of the most challenging issues. There are three separate governing agencies for teacher preparation programs – the state department of education, the teacher certification agency, and the higher education governing agency. There are many times regulations are implemented often without thinking about the impact on teacher education programs, including structures not directly related to the regulations. For example, the teacher certification agency recently released a regulation that all middle and secondary teachers had to take a content area literacy course. On the surface this does not appear to be a bad idea. But a deeper analysis of the regulation reveals that instead of thinking about ways to integrate those ideas into current coursework and teach it in context, the regulation requires a new course taught by an accredited literacy faculty member. The result? The creation of an isolated course that has no field experience component and had to be squeezed into an already credit-heavy STEM major. Moreover, the number of hours for an undergraduate program are fixed—so the result is not merely adding a course, but now a course must be removed.

As the Kentucky partnership continues its transformation endeavors, MTE-P will be able to help think about scaling beyond local change; the expansion of partnerships is important. Local change is great, but how do you get beyond local change? How do you scale that really great idea that has made an impact? What does scaling even look like? How do we, together, better advocate for our teachers?

DeVonne Smalls – Richland County School District One, South Carolina

The University of South Carolina (UofSC) partnership faces many challenges, including secondary mathematics teacher shortages, poor teacher retention, and declining high school enrollment. The biggest obstacle in the UofSC partnership is filling all of their mathematics teaching positions needed by schools and districts in our state. Local schools too often begin the school year hiring long term subs.

While preservice teachers at UofSC have fantastic teacher placements, that's not always their reality when they get hired at their own schools. Through a new summer induction program, the UofSC partnership is trying to introduce them to these potential challenges and provide more support mechanisms early in their career.

Within the UofSC partnership, enrollment levels at the local high schools continue to trend downward. This has especially affected the ability of schools to offer specialized mathematics courses. While there is a desire to offer these courses, the low student population will not support them. Further, teachers and district personnel across the partnership struggle to find time to meet and take action around the challenges such as the inability to sustain specialized mathematics course. The UofSC partnership is hoping that expanding the partnership to include more K12 schools might help leverage resources and aid in recruiting new teachers.

MTE-P has been a great support for the UofSC partnership. There have been several opportunities within the partnership to help meet the goals of MTE-P and their local partnership. UofSC plans to add a capstone course that helps to tie the education coursework more effectively to the mathematics major. The opportunities provided to network with and share resources with other partnerships and to learn from the work of various RACs has been extremely helpful. Additionally, valuable resources (e.g., MCOP^2, Recruitment Guide) have been a great help in making partnership transformations. As the UofSC partnership looks to the future, they would like to see the development and offering of cross-institutional courses.

Wendy Smith – University of Nebraska Lincoln

Sometimes tinkering is what you need. Sometimes going all in is what you need. – Wendy Smith

The University of Nebraska-Lincoln (UNL) has gone through five years of institutional change. They started off tinkering with small ideas, but found that strategy ineffective. Instead, they needed bigger changes to what they were doing—so they decided to go "all in," with bringing active learning into their first-year mathematics courses.

Two-thirds of UNL freshmen take a mathematics course in their first semester; no other department gets close to seeing that many freshmen. Spurred by an administrative emphasis on graduation and retention rates, the mathematics department took a deeper look at their local and benchmark data. Unsurprisingly, they found that mathematics grades correlated very highly with retention and 5-year graduation rates. Their pass rates in the mathematics courses ranged from 40% - 70%, depending on the instructor. They also noticed that students passed Calculus I at higher rates when they took it right out of high school compared to when they took College Algebra at UNL prior to Calculus I. Wanting to get ahead of any top-down changes, the mathematics department decided to implement "active learning," first in their College Algebra courses. They targeted these high-enrollment courses because they would have a more dramatic effect on retention from freshman to sophomore year and the courses were generally taught by graduate teaching assistants (GTAs) and adjuncts (e.g., very short institutional memory). In order to help prepare the GTAs for teaching the courses with this new pedagogical approach, the mathematics department started requiring them to take a teaching course. Surprisingly, the department only had to sell the change the first year; thereafter, they didn't have to sell it at all. The mindset was already established and normalized, "This is how we do it. This is just how you do it when you're at UNL."

Early efforts aided in the dramatic transformation: common syllabi, common exams, and common grading all helped pave the way for the change. There was already a mathematics resource center for tutoring. While tinkering generally didn't work, what really paved the way as a new department chair who vocally advocated for active learning for *all* mathematics courses.

While there were lots of strategies (see Figure 1) that aided in the transformation, a key to the sustained change was the First-Year Mathematics Faculty Taskforce. The taskforce was there to help review elements of the active learning transformation, for example, to make sure the content was still at an appropriately challenging level. The taskforce reviewed exams and determined the new exams were actually more rigorous with active learning than they had been previously.

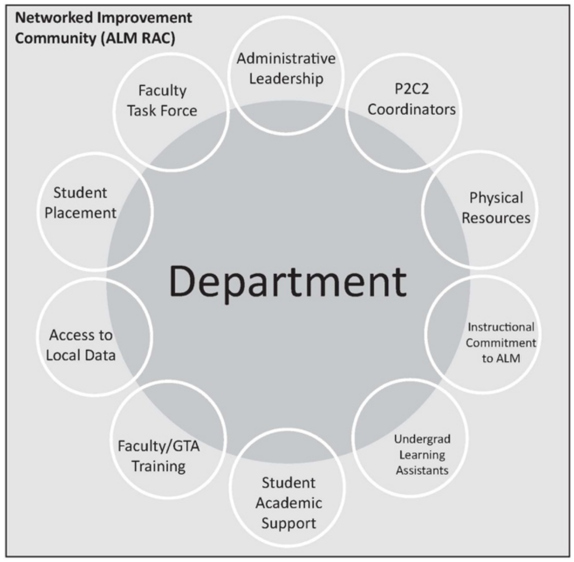

Figure 1. Elements of a common vision for effective mathematics instruction at UNL.

There are still challenges that must be faced within this transformation process at UNL. Issues remain with student placement into courses. Access to local student data is still unresolved, particularly for data needed to compare programs at UNL to those of peer institutions.

The keys to the transformation success were many, but overall, when you raise the expectations for the students, you have to raise the level of support so students can meet these expectations. Part of that support at UNL was the implementation of learning assistants. Another part was physical resources. UNL renovated classrooms to include movable oval tables and chairs, as well as white boards that went all the way around the room. Additionally, the mathematics department was able to convince the university that Active Learning was more like a physics lab than a traditional lecture class, so now instructors have more minutes for the same number of credit hours. This allows students the extra time needed to help support and provide an environment that fosters deeper conversations. Finally, a new position for Director of First Year Mathematics was created.

College Algebra and Calculus I courses have been transformed. Calculus 2 is next and Business Calculus is down the road. Through this dramatic transformation in the pedagogy of the first-year mathematics courses and within the mathematics department, failure rates have been cut in half. Having the local and national data really helped to bring the faculty on board.

Robin Hill – Kentucky Department of Education; President of Association of State Supervisors of Mathematics

Each of these four examples indicate the need and opportunity to partner with your state agencies in the transformation process. State agencies can help to work strategically, bringing additional people to the table and helping to influence policy. Bringing the right people together in your partnerships can be the key to success. Connections with state agencies will strengthen both partnership teams and the RACs. If you're not talking to the right people, then it's difficult to enact change.

For implementing transformation, MTE-P provides a tremendous opportunity. The examples given here today are evidence that there really is and can be institutional change. Getting people to work together and to buy into the change is key. Some tips for transformation include:

1. Don't oversimplify everything. Everyone might not see things as we see it. Be intentional about your partnerships and being intentional and what roles each member plays.
2. Make sure you're clear and transparent about what happens. Transformation doesn't happen miraculously or instantaneously.
3. There will be a "Dawn of Reasoning"; the realization that certain efforts are going nowhere. Pushing on the right drivers as well as sharing the load and the information (see #2) can make your efforts smoother. Partnering with state departments of education can really help here.
4. Realize that you're not in this alone.

Transformation is complicated, a little messy and hard work. Some of the efforts may at times like you're herding cats. Managing the complexity of many moving parts and partnerships to transform your programs may seem endless and sluggish. There will be some scratches, bumps and bruises along the way. But this work is worth doing because it's going to lead to stronger mathematics teachers. This goal that is sought is shared by the hundreds of individual members of the MTE-P, and broadly by so many more.

MTE-Partnership Conference Reactants[1] [2]

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Three friends of the Mathematics Teacher Education Partnership (MTE-P) were invited to participate then provide their reactions to the conference, Dr. Karen King, Ms. Diana Suddreth, and Dr. W. James Lewis. The three were petitioned in an effort to obtain a range of perspectives related to mathematics education. Dr. Karen King presently serves as Program Director at National Science Foundation (NSF). Her background is in mathematics education, with a strong focus on policy. Ms. Diana Suddreth is Director of Teaching & Learning at the Utah State Office of Education. She offered a broad, P-12 perspective, again particularly focusing on policy. And the third reactant, Dr. W. James Lewis, represents a mathematician's perspective. Dr. Lewis presently serves as Deputy Assistant Director, Education and Human Resources at the National Science Foundation on short-term appointment from his position as Professor of Mathematics at the University of Nebraska. Each reactant had fully participated in the conference, including contributing to the working groups. Further, each has been an advisor to or active participant since the MTE-P's inception.

Karen King

Dr. King began her comments by recognizing that in her plenary, Dr. Suzanne Wilson framed mathematics teacher education inside larger conversations around teacher education and educational reform. Dr. King indicated that her own comments would begin and then return to these broader issues, along the way bringing to the table her policy perspective. She first spoke broadly of measures in educational research, then turned to specifics of the MTE-P conference, including her thoughts about two specific events she attended, the Clinical

[1] King, Suddreth, and Lewis delivered this feedback as a reactant panel at the conclusion of the conference. Lawler wrote this paper to summarize their comments, drawing from their slides and notes, audio recording of the talks, and notes kept as they spoke.

[2] King and Lewis provided reactions while serving at the National Science Foundation, and Suddreth while serving at the Utah State Office of Education. The comments or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or the Utah State Office of Education.

Experiences RAC work sessions, and the Equity and Social Justice Pre-Session. She concluded with the broader challenges of equity work in education.

Dr. King first addressed the challenges of measurement, appreciating the plenary panel on measurement in the context of working in Networked Improvement Communities (NICs). Dr. King noted that measuring the impacts of policy and teaching practices has not been a strength of mathematics education, or more broadly, of teacher education. The measurement challenge is exacerbated because of tensions, such as those between validity and reliability, or the need for measures to be both practical (timely, useful, accessible, do-able etc.) and consequential (meaningful, understandable, etc.). Such qualities for measures are difficult, particularly in school settings. Yet policy makers, school administrators, and other stakeholders call to measure what is easy, instead of focusing on measuring what is important.

Science improves when we find new ways to measure. For example, education has an exceptionally strong qualitative research tradition; however, quantitative measures for the complex constructs unearthed by these qualitative studies are few. Dr. King again echoed Dr. Wilson's opening plenary called for more thoughtful strategies to communicate what we learn by, for example, employing new ideas in data visualization. Finally, Dr. King reminded us to prepare doctoral students for this sort of measurement work by incorporating in our programs new ways to think about, conduct, and report data. She pointed out that understanding and using measurement and data are also critical for programs for master's students in mathematics and administration because these programs often yield the future formal and informal leaders in the field.

During the conference, Dr. King participated in the Clinical Experiences RAC (CERAC) activities and offered two summative thoughts regarding their work. First, she remarked that the big goals for the group seemed to be well-defined; however, Dr. King suggested that the group could benefit by identifying more specific, actionable learning goals for each strategy. Second, she encouraged the CERAC clarify the difference between structures for the Clinical Experience, and strategies used with pre-service teachers within the Clinical Experiences.

Dr. King also participated in the Equity and Social Justice Pre-session. She noted that the constructs equity, social justice, and diversity are not the same; however, these terms are often used interchangeably in education. Given this background, she inquired about how MTE-P approaches school integration as an equity issue, as noted by Secretary of Education John King. For example, she asked whether it is possible for schools be separate and equitable. Specifically, she noted that a setting in which all students in a classroom are minority, but the same minority, is not generally defined as ethnically or racially diverse. While the setting may provide cultural experiences useful for preservice teachers it does not provide experience with a diverse context. Furthermore, understanding diversity includes understanding that being black, for example, is not the singular dimension of one's identity. To fully address issues of diversity, attention must be given to the full character of each child. Simple chunking of individuals into groups by singular characteristics is misdirected and counterproductive, and misses the fact that there is more variation within groups than between them. Equity is about everyone; a person may have a set of privileges associated with education and class; but also face historical disadvantages as a woman and an African-American. Broad strokes are insufficient in this work. Everyone needs some different kind of support. Dr. King reminds us that equity is complicated, and here she has pointed more strongly to questions and challenges posed by work, rather than intending to be prescriptive.

Dr. King applauds the MTE-P community for taking on these issues, but to take care about essentializing students based on their group. She encouraged us to investigate research outside of mathematics education, echoing the calls of Dr. Wilson's plenary, to discover what other fields have learned about the potential perils of well-intended efforts for diversity training. As a second example of how research outside our field can be informative, she noted that business has learned quite a bit about getting people to things they may not wish to do, especially with regards to attracting people to jobs.

Diana Suddreth

Ms. Suddreth highlighted the commonalities she observed across the RACs, including funding structures; high quality instruction; a focus on evidence, arguments, and warrants; working with students; community engagement and institutionalization. She noted these elements seemed to speak to the cycle of change driven by the need to respond to new ideas and concerns.

She next turned to the opportunities and challenges of the work such as: needs of a changing workforce; time constraints; partnerships with state agencies, and shortages of K-12 teachers. Ms. Suddreth reminded us that if we don't turn our great ideas into actionable innovations that address students, schools, and other constituents, all these ideas become nothing more than discussion at a meeting. She highlighted the NIC research design, especially the PDSA cycles that allow in-time innovation trials that foster a continuing cycle of evidence-driven learning and improvement.

Her final challenge was to broaden our engagement with our communities. People in positions like hers, that is, associated with state departments of education or similar agencies, need to know what projects are being implemented in their domains in order to be fully supportive. These individuals need to understand the roles and goals of both of MTE-P and the participating systems, institutions, teams, and teachers in order to function as an advocate and useful partner. She reminds us that the changes we seek are not solely about mathematics, there are many additional theoretical and practical issues involved in better preparing more secondary mathematics teachers. Although much other work is being carried out that we can learn from, the mathematics community has been clearly important to and a leader in general teacher preparation. This history of the role of mathematics education can and ought to be leveraged, both in funding and in practice.

W. James Lewis

Dr. Lewis stressed that he was offering his own views as someone who has been involved in the MTE-Partnership from the beginning, and not as an employee of the National Science Foundation (NSF). He provided a historical perspective on the MTE-Partnership project, recalling the initial idea for this project emerged at a Science and Mathematics Teacher Imperative (SMTI) conference in 2011. Dr. Gary Martin pitched the idea, and soon afterwards with the support of an NSF planning grant, the first MTE-P meeting occurred in March 2012. A strength of the community that has since emerged is the long-term and stable membership that maintains a continuity, bolstered by new members that are the result of growth and transitions.

MTE-P has ambitious goals, to seek a national consensus on the preparation of secondary mathematics teachers, to promote partnerships, to develop a research and development agenda, and to set a national agenda for the issues related to mathematics teacher preparation. Specifically, this conference builds on these goals to begin to consider the challenges of transformational change.

Dr. Lewis noted the design of the conference as a working conference is somewhat unique, a working conference. He observed the participants were very engaged and quite impressive. Among the highlights he noted were the updates from RACs of work since the last conference, the equity and social justice work session, the evening mixer, the plenary session on data and measures in the NIC research paradigm, and the 15 research presentations. Because of the richness of the research presentations, he commented that it was unfortunate that each of us could only attend three.

Dr. Lewis asked, “At this stage in the growth of the MTE-Partnership, it may be a good time to take stock; to ask how are we doing?” He suggested that a challenge is to make equity and social justice issues more explicit, but commented that the community is off to a good start. A second challenge is to build joint purpose and identity. He offered the assessment that at the present time the MTE-P purpose and identity of the seems to be productive and appropriate but said that there is a small chance that the RACs contribute to a compartmentalization. His view is the community should intentionally create networks and structures that do not allow these divisions. Social events like the mixer and shared social and sharing communities like Trellis are good approaches to address this challenge.

Dr. Lewis suggested another challenge is that there seems to be a need to accelerate the work of the RACs. He admitted he may be impatient; but without noticeable change across many of the RACs, participants may experience fatigue. Another challenge is that we have reached a developmental point in which it is time to give greater focus to building to program transformation. There is still much work to be done to move from tweaking to transforming.

Finally, while MTE-P is doing good work, some consideration should be given to how that work can be strengthened. Repeating Diana Suddreth, he argued there is a need to build more ties with K-12 partners. Additionally, the community needs more mathematicians (interested in education) at the table; MTE-P will not achieve its goals if its only members are in departments of teacher education. Similarly, the community needs more department chairs and other campus leaders to be active participants—especially to achieve program transformation.

Summary

Each of the reactants were very positive about the work being done by the MTE-Partnership and acknowledged the strength and commitment of the community. Common themes in the feedback focused on the challenges faced, encouraging focus for the next stages in the work. This includes continuing the robust structure of the NIC research design, but being more committed to developing robust measures and sharing results with the larger community involved in the preparation of secondary mathematics teachers.

The reactants also advised that there be increased partnerships with K-12 districts, state leadership, mathematicians, and university campus leadership—the charge of program transformation is complex and involves many constituents. Not only is program transformation complex, so is the preparation of secondary mathematics teachers; particularly the efforts to change current practices in mathematics education. The change efforts MTE-P strives for reach beyond merely the mathematics content or curriculum design, but involves teaching, school structures, and societal norms as well.

A final commonality among the reactants comments were commendations to MTE-P for its robust and productive history of work, and for establishing a community founded in a research-driven effort to transform the preparation of secondary mathematics teachers.

RESEARCH ACTION CLUSTER REPORTS

Clinical Experiences[1]

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Teacher preparation programs face significant challenges in providing secondary mathematics teacher candidates with quality clinical experiences. The problem is two-fold:

1. There is an inadequate supply of quality mentor teachers to oversee clinical experiences. Too few teachers are well versed in implementing the CCSS and teachers are especially inexperienced with embedding the standards for mathematical practice into their teaching of content standards on a daily basis.
2. Bidirectional relationship between the teacher preparation programs and school partners in which clinical experiences take place are rare. Such relationships that reflect a common vision and shared commitment to the vision of CCSSM and other issues related to mathematics teaching and learning are critical to the development and mentoring of new teachers.

The work of Clinical Experience RAC (CERAC) encompasses a number of the principles and principle indicators from the MTE-Partnership Guiding Principles, including fostering partnerships between institutions of higher education, schools and districts, and other stakeholders such as state departments of education and is focused on preparing teacher candidates who promote student success in mathematics, as described in the Common Core State Standards for Mathematics (CCSS-M) and other college- and career-ready standards. In the CERAC higher education faculty and partner school districts and schools work together to actively recruit, develop, and support inservice master secondary mathematics teachers who can serve as mentors across the teacher development continuum from preservice to beginning teachers. Moreover, the CERAC helps to ensure that teacher candidates have the knowledge, skills, and dispositions needed to implement educational practices found to be effective in supporting all secondary students' success in mathematics as defined in the CCSS-M and other college- and career-ready standards.

The CERAC consists of 24 university led teams, each consisting of at least one mathematics teacher educator, a mathematician, and a school partner. The CERAC is divided into three Sub-RACs based on the three types of field experiences that we are implementing to

[1] The RAC Promo Sheet, presented during the opening of the conference to report on current activities of the RAC, can be found after the reference list.

Lawler, B. R., Ronau, R. N., & Mohr-Schroeder, M. J. (Eds.). (2016). *Proceedings of the fifth annual Mathematics Teacher Education Partnership conference*. Washington, DC: Association of Public Land-grant Universities.

meet the goals that we set forth in our primary drivers and our aim statement. The Sub-RACs are: Methods, Paired Placement, and Co-planning and Co-teaching. Each Sub-RAC is implementing Plan-Do-Study-Act (PDSA) cycles based on their goals and objectives. Teams work together via conference calls, email, and the Trellis platform. We use Dropbox and Trellis as a way of sharing files and materials. We have held face-to-face meetings as a whole RAC that included breakout meetings for Sub-RACs. The SUB-RACS have overlap areas that drive and focus the RAC as a whole, such as the emphasis on the mathematics teaching practices (National Council of Teachers of Mathematics [NCTM], 2014), PD for mentors related to the CCSS and mentoring mathematics teacher candidates, and outcome measures. There are also specific goals to be attained within each of the Sub-RACs. Each Sub-RAC has developed their own specific research questions.

Methods Sub-RAC

The Math Methods Sub-RAC of the CERAC includes members from10 institutions of higher education and public school districts. Our work has focused on strengthening the connection between the university based methods courses and the field experience component associated with the methods courses. We have given particular attention to increasing and deepening teacher candidates' (TCs') and mentor teachers' (MTs') understanding and implementation of the Common Core State Standards for Mathematical Practice (CCSSO, 2010). We created a Standards for Mathematical Practice (SMPs) module available for use in methods courses and the associated field experience. The module includes three activities designed to support TCs and MTs in meeting the following goals:

Activity 1

- TCs will recognize that for the typical student, U.S. mathematics classrooms lead them to develop unproductive habits related to mathematics.
- TCs will begin to consider how their actions as teachers might support the development of a different, more productive set of habits (e.g., the mathematical practices).
- TCs knowledge and understanding of the SMPs will increase.

Activity 2

- TCs will engage in the SMPs as "students" while exploring high school geometry content they are likely to teach.
- TCs will apply the knowledge gained from Activity 1 to identify and discuss the SMPs they experienced as they worked on the Properties of Quadrilaterals task and identify how the facilitator supported their engagement in the SMPs.
- TCs gain a deeper understanding of teacher moves that support student engagement in the SMPs using the Park City Math Institute (PCMI) Rubric.

Activity 3

- TCs and MTs will watch a video clip of a lesson designed to engage students in the SMPs and then discuss their observations of the students during the lesson.
- TCs and MTs will consider how what they observed in the video might impact their teaching.

The SMP Module has been implemented by six members of the Methods Sub-RAC and revised based on their experiences. We are currently seeking additional methods instructors interested in incorporating this module into their methods courses.

Our next steps include the development of a Lesson Design module. The goals of this module are for TCs 1) to recognize the need to approach lesson planning with a focus on student learning and engagement; and 2) begin to integrate select Mathematics Teaching Practices (NCTM, 2014) into their planning and instruction practices. This module will be piloted by Methods Sub-RAC members starting in the fall of 2016.

Co-Planning and Co-Teaching (CPCT) Sub-RAC

The Co-Planning and Co-Teaching (CPCT) Sub-RAC includes members from 10 institutions. Our goal is to enable mentor teachers and teacher candidates to carefully plan and subsequently use various co-teaching strategies during clinical experiences. We focused on six co-teaching strategies, namely: *one teach, one observe*; *one teach- one assist*; *parallel teaching*; *team teaching*; *station teaching*; and *alternative teaching* (Friend et al., 2010; Murawski & Spencer, 2011). CPCT is a paradigm shift from traditional approaches to clinical experiences. Hence, the Sub-RAC members has placed an emphasis on training and disseminating information about how to implement CPCT effectively. Additionally, the members facilitated CPCT activities at their respective sites, and assisted with data collection to provide insight into the nature of implementation of CPCT during clinical experiences.

To date the CPCT Sub-RAC has engaged in a rigorous effort to disseminate research and scholarship to a wider audience. Members of the group have facilitated professional development workshops, published articles in a journal and multiple conference proceedings, and presented at national and international conferences about preliminary findings and practical means to implement CPCT. The CPCT Sub-RAC plans to solicit for funding to host a working group meeting to produce a deliverable (i.e., book and/or video) that would clearly explain how to integrate CPCT into clinical experiences. Overall, the CPCT Sub-RAC has been actively seeking to increase the visibility of CPCT in the literature and at educational meetings.

During the MTE-P 2016 annual conference, members of the CPCT Sub-RAC engaged in refining our *Annual Perspectives in Mathematics Education 2017* manuscript that describes how the group uses improvement science to transform clinical experiences, presented three brief research reports, articulated the PDSA cycles for the next academic year, revised multiple instruments used to gather data about the *process measures*, reflected on challenges at various institutions that hindered data collection efforts, planned to embed equity and social justice into our CPCT activities, suggested that CPCT training badges ought to be used, and explored funding possibilities to produce a publishable deliverable and support the group's research efforts.

Looking ahead, the CPCT sub-RAC will continue to implement CPCT at their respective institutions, garner data and engage in PDSA cycles, in an effort to transform clinical experiences. With careful planning, and allocation of time to gather data, the team intends on scaling up their research activities.

Paired Placement Sub-RAC

The Paired Placement Sub-RAC is comprised of members representing five institutions. The Sub-RAC focuses on the paired placement model for student teaching in which two prospective teachers are paired with a single cooperating teacher. The cooperating teacher provides purposeful coaching and mentoring, and the two pre-service teachers offer each other feedback, mentoring, and support (Mau, 2013, Leatham & Peterson, 2010b). As a Sub-RAC, we read articles (Goodnough, et al. 2009; Leatham & Peterson, 2010a & 2010b; Mau, 2013) to learn about the model. One team implemented the model fall 2013 and reported to the other teams about its findings. The two teams used this information along with information from the literature to prepare mentor teachers and candidates for the experience Spring 2014. Teams also worked with their participants to adjust the model within their context utilizing PDSA cycles. Teams monitored the process throughout the semester. Teams met via conference call to discuss the results of the implementations and what they would do differently. Teams created professional development modules, syllabi, and measures Fall 2014. Teams implemented the model again Spring 2015 utilizing suggested improvements from previous iterations. One pair was implemented in the fall of 2015, and six pairs were implemented spring semester 2016.

Through PDSA cycles and data collected from participants, we are learning much about the model. We have found that it allows teacher candidates to really focus on student learning and the craft of teaching. Teacher candidates and mentor teachers who have experienced this model believe that it benefits all of their growth in teaching as well as the students' growth in learning mathematics. They also stated that the model has helped them to become more collaborative.

During the conference, we acclimated new members and revised and streamlined our measures. We also made plans to implement the revised workshops and syllabi in the spring semester of 2017. We intend to submit proposals to speak at appropriate venues and submit a manuscript related to our work. We will also work in concert with the other Sub-RACs to seek funding to support the work.

We have given presentations about the model at conferences and are working on submitting papers to journals. Our goal is to refine the workshops and syllabi so that they can be adapted to different contexts.

CERAC

The CERAC as a whole has made good progress toward our goals. We have created measures (Mathematics Teaching Practice Survey and others) to help with gauging the growth of teacher candidates involved in our programs, and we are also using measures developed by others. Measures used across the three Sub-RACS include the following:

- *MCOP²* – The Mathematics Classroom Observation Protocol for Practices in a K-16 mathematics classroom instrument (Gleason, Livers, & Zelkowski, 2015).
- *MTE-P Completer Survey* will show how well prepared the teacher candidates feel based on the experiences that they had in their programs.
- *Mathematics Teaching Practices Survey* used to determine the level at which prospective secondary teachers are engaged with NCTM's (2014) Mathematics teaching practices.

As a RAC, we plan to pay explicit attention to equity and social justice issues in the next iterations of our modules. Even though we have included issues of equity in our driver's diagram, we feel that it is important to make it known in our products that access, equity, and empowerment for each and every student is important to our work.

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MTE-Partnership
Solicitation for Participation in the
Clinical Experiences RAC
April, 2016

Problem Addressed

Teacher preparation programs face significant challenges in providing secondary mathematics teacher candidates with quality clinical experiences. The problem is two-fold:

1. There is an inadequate supply of quality mentor teachers to oversee the experiences. This is related to the quantity of teachers who are well versed in implementing the CCSS, especially embedding the standards for mathematical practice into their teaching of content standards on a daily basis.
2. There needs to exist a bidirectional relationship between the teacher preparation programs and school partners in which clinical experiences take place. This relationship should reflect a common vision and shared commitment to the vision of CCSSM and other issues related to mathematics teaching and learning.

The work of Clinical Experience RAC encompasses a number of the principles and principle indicators from the MTE-Partnership Guiding Principles, including fostering partnerships between institutions of higher education, schools and districts, and other stakeholders such as state departments of education and is focused on preparing teacher candidates who promote student success in mathematics, as described in the Common Core State Standards for Mathematics (CCSS-M) and other college- and career-ready standards. In this RAC higher education faculty and partnering school districts and schools work together to actively recruit, develop, and support inservice master secondary mathematics teachers who can serve as mentors across the teacher development continuum from preservice to beginning teachers. Moreover, the clinical experiences RAC helps to ensure that teacher candidates have the knowledge, skills, and dispositions needed to implement educational practices found to be effective in supporting all secondary students' success in mathematics as defined in the CCSS-M and other college- and career-ready standards.

General Approach

- The RAC is divided into three Sub-RACs based on the three types of field experiences that we are implementing to meet the goals that we set forth in our primary drivers and our aim statement.
- Each Sub-RAC is implementing PDSA cycles based on their goals and objectives.
- Teams work together via conference calls, email, and the Trellis platform.
- We utilize Dropbox as a way of sharing files and materials.
- Have had face-to-face meetings as a whole RAC with breakout meetings for Sub-RACs.
- There are overlap areas that focus the RAC as a whole, such as the emphasis on NCTM's mathematics teaching practices, PD for mentors around the CCSS and mentoring mathematics teacher candidates, and outcome measures.
- There are also specific goals to be attained within each of the Sub-RACs.
- Each Sub-RAC has specific research questions, which they are addressing.

Who We Are

Methods	Paired Placement	Co-Plan/Co-Teach
University of North Dakota MTEP: Michele Iiams Cathy Williams *USC Midlands MTEP:* Jan Yow DeVonne "Vonnie" Smalls Beth Oliver Nevermind Chigoba *West Alabama Partnership, University of Alabama:* Jeremy Zelkowski Jim Gleason John Abby Khalilian Karla Moore Jill England Melinda Williams *GSU MTEP:* Gregory Chamblee Missy Jenkins Sharon Taylors Pier A. Junor Clarke *California State University, Fullerton* Mark Ellis *California State University, Northridge* Ivan Cheng *California State University, San Bernardino* Su Liang *Oregon MTEP:* Rebekah Elliott Wendy Aaron	*Central Alabama MTEP:* Marilyn Strutchens Brooke Barron Peggy Dagley Huajun Huang *Montana MTEP:* David Erickson Bill Lowney Lee Brown Jim Hirstein *East Central Texas MTEP:* Jennifer Whitfield Dawn Parker Laura Wilding *New Mexico State University MTEP:* Lida J. Uribe-Flórez Ted Stanford Silvia Celedón-Pattichis Tom Gruszka	*Tampa Bay Area MTEP:* Ruthmae Sears Fernando Burgos Gladis Kersaint Julie Wagner *North Carolina State University MTEP:* Karen Keene Karen Norwood Allison McCulloch Karen Hollebrands *East Carolina University MTEP:* Charity Cayton Maureen Grady Ron Preston Rose Sinicrope. *UCF MTEP:* Janet Andreasen Melissa Dagley Amanda Ellis Bryan Zugelder *California State University, Chico:* Jennifer Oloff-Lewis: Mary-Elizabeth Matthews Kerrie Girt *California State University, San Bernardino:* Catherine Spencer *California State University, Northridge* Ivan Cheng Julie Gainsburg *California State University, Sacramento:* Stephanie Biagetti Elaine Kasimatis *OSU MTEP* Patti Brosnan Marguerethe Jaede

Current Progress

RAC Activities

- In March 2015 we submitted a Phase 4, Robert Noyce Research Grant to the National Science Foundation. While not recommended for funding, we plan to revise and resubmit for the 2016 Noyce competition.
- Sub-RAC leaders attended the Carnegie Foundation for the Advancement of Teaching Networked Improvement Community Design Learning Lab in spring and fall 2015.
- We are disseminating our work through conference venues, such as AMTE's Annual Meeting and SMTI's Annual Meeting.
- Some of our members will be presenting their work at the 13th International Congress on Mathematical Education (ICME-13), July 24 – 31, 2016 in Hamburg.

Early Field Experiences within Methods Sub-RAC

- Teams revised and implemented a module designed to strengthen teacher candidates' and their mentor teachers' understanding of the CCSS Standards for Mathematical Practice (SMP). The opportunity to build a productive teacher candidate and mentor teacher relationship is an additional goal. In addition to increasing teacher candidates' and mentor teachers' knowledge of the SMP the module provides an opportunity for the teacher candidates and mentor teachers to develop a relationship and common language around these ideas.
- Teams developed a survey to measure the possible effects of completing the module activities on teacher candidates' and mentor teachers' understanding of the SMP.
- Teams developed and employed additional measures for the SMP Module: Activity "Exit Slips" for teacher candidates and an implementation survey completed by the methods instructor.
- Teams created and are piloting a survey on teacher candidates' knowledge and use of the Mathematics Teaching Practices.

Co-Plan/ Co-Teach Sub-RAC

- Teams created instruments and professional development training module relevant to CPCT, and received feedback from all members of the group.
- During the 2014-2015 academic year, the CPCT Sub-RAC conducted a pilot study to examine mentor teachers' and teacher candidates' knowledge about the Common Core State Standards for Mathematics – Content Standards and Standards for Mathematical Practice, as well as documented their beliefs and instructional practices.
- During 2015- 2016 academic year, the team revised the PDSA cycle for Cycle 2, and increased its membership.

Paired Placement Sub-RAC

- Teams read about the model.
- One team implemented the model fall 2013 and reported to the other teams about its findings.
- The other two teams used this information along with information from the literature to prepare mentor teachers and candidates for the experience Spring 2014.
- Teams also worked with their participants to adjust the model within their context.
- Teams monitored the process throughout the semester.
- Teams met via conference call to discuss the results of the implementations and what they would do differently.
- Teams created professional development modules and measures fall 2014.
- Teams implemented the model again Spring 2015 utilizing suggested improvements from previous iterations.
- One pair was implemented in the fall of 2015 and six pairs are being implemented spring semester.

Opportunities for Engagement

Early Field Experiences within Methods Sub-RAC

1) Implementing SMP module and contributing to data collection; and 2) Collaborating on the development of additional modules and measures of module effects on teacher candidates and mentor teachers

Co-Plan/ Co-Teach Sub-RAC

1) Developing, utilizing, and sharing instruments used to measure the influence of the co-teaching model; 2) Implementing and examining teacher candidates' experiences throughout their field-based preparation (i.e., practicum and internship); and Studying the influence of professional development on the success of the co-teaching model.

Paired Placement Sub-RAC

1) Developing, utilizing, and sharing instruments used to measure the influence of the paired placement model; (2) Implementing and examining teacher candidates experiences throughout their field-based preparation (i.e., practicum and internship); and (3) Refining and studying the influence of professional development and orientation sessions on the success of the paired placement model.

Actively Learning Mathematics: Toward Departmental Transformation of the Teaching of Undergraduate Calculus[1]

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The overarching goal of the Active Learning in Mathematics Research Action Cluster (ALM RAC) is to improve student success with undergraduate mathematics in Pre-calculus through Calculus 2 (P2C2). The ALM RAC developed curriculum materials that focused on effective teaching practices, which are supported by learning environments that are more conducive to student interaction, reasoning, and problem solving. Gaining faculty buy-in and institutional leadership support was necessary to encourage and, in some cases, fund Graduate Teaching Assistant training aligned with the goals of the project. Moreover, training should include undergraduate learning assistants, employed by many campuses to enhance student experiences with group activities and engagement in mathematical activities and explorations.

Statement of Problem and Aim

Student success in undergraduate mathematics has significant implications regarding student choice of STEM majors and related careers. Even students who do not choose to major in STEM, success in entry-level undergraduate mathematics courses such as calculus can make or break their decision to persist in postsecondary education (Ferrini-Mundy & Graham, 1991; Moreno & Muller, 1999; Rasmussen, Ellis, & Bressoud, 2015; Subramaniam, Cates & Borislava, 2008). Studies of instructional improvements in undergraduate calculus that have been characterized as Active Learning or Inquiry Based Learning have demonstrated improved DFW rates, improved student dispositions towards mathematics, and persistence in taking subsequent courses. Nevertheless, in spite of the accumulation of findings supporting ALM there are institutional challenges that preclude its adoption and sustained support in university mathematics departments (Ganter, 2001).

[1] The RAC Promo Sheet, presented during the opening of the conference to report on current activities of the RAC, can be found after the reference list.
[2] This brief was developed from various sources written collaboratively by multiple members of the ALM RAC. These sources include planning documents, meeting minutes, and circulars developed to help communicate the goals and activities of the ALM RAC.

The challenges inherent in institutional change include political, curricular, and cultural features of departments and colleges that resist change and cling to the status quo. Overcoming these challenges requires a commitment to will building, curriculum development, professional development, and seemingly superficial features such as the way tables can be organized in a classroom. Implementing these multiple changes to departmental structures, processes and communication requires complex skills, knowledge, and resources that university faculty are not traditionally motivated nor incentivized to acquire or develop. Teaching calculus in a manner that could be characterized as student-centered is not typically found in tenure and promotion statements, nor is it implied in faculty meetings or departmental communication. However, recent initiatives by the White House Office of Science and Technology Policy and the National Science Foundation in support of active learning in STEM education could have some influence the priorities of universities, mathematics departments and calculus instructors.

How we have addressed the problem to date

Over the past three years, we have worked collaboratively to improve instruction in introductory calculus courses. Initially, with funding support from the Helmsley Charitable Trust. The expansion of our curriculum development and data collection efforts resulted in a number of partners discovering a department commitment to infusing ALM in undergraduate calculus courses can result in early demonstrable improvements in the DFW rates and persistence of students in subsequent courses.

While the contexts across the twelve partner institutions involved in the ALM RAC are quite different, requiring somewhat different approaches to implementing ALM, we have been able to learn from each other’s efforts. We have exchanged and co-developed instructional resources, used common measures to document student dispositions, and have regularly discussed the local models used to support learning environments that are more conducive to ALM. At least four campuses adopted the “learning assistant” model that was developed by the University of Colorado Boulder, while West Virginia used Graduate Teaching Assistants in a similar role. Discussions across campuses have helped to clarify the approaches used and have identified the critical role of institutional change in promoting ALM.

The ALM Networked Improvement Community. The members of the ALM RAC understand that challenges inherent in changing instructional practice are, in part, due to systemic nature of teaching in classrooms. The decisions made by an instructor to teach in a particular manner are derived from their interpretation of department goals, the resources allocated to time and space, the design of instructional activities, the opportunities for professional learning, and the department’s norms for assessment. Changing classroom practice requires alignment and coordination of multiple parts of the system to support common goals for student learning. Hence, the need for an ALM Networked Improvement Community (ALM NIC) so that one institution is solely responsible for developing a knowledge base while developing resources for instruction and professional development. Our ALM NIC communicates and documents lessons learned as well as distributes a multitude of resources to reduce the burdens related to preparation of IRB protocols and instructional resources.

Products developed. Two major contributions to resource development have resulted from our efforts in infusing ALM in the P2C2 sequence. Faculty at the University of Nebraska Omaha and University of Colorado Boulder co-developed instructional materials that could be used to replace lessons for calculus topics; and our interest in document shifts in student dispositions resulted in the adaptation, refinement and validation of a student survey.

Tactile + Activities = TACTivities. Inspired by Angie Hodge at a colloquium she facilitated at University of Colorado Boulder, faculty at University of Colorado Boulder partnered with Hodge in the design of TACTivities[3] for calculus. The characteristics of these TACTivities generally included two or more different types of mathematical representations printed on cut cardstock that could be organized to suggest either fulfillment of a complete set, or a categorization scheme that could be justified by students. For example, Figure 1 shows a portion of the Definite Integral Dominos TACTivity. As students touched and moved cards to pair representations, they would discuss their reasons for doing so. Often this would elicit peer feedback either affirming or countering the decision to pair the representations on different sides of the cards.

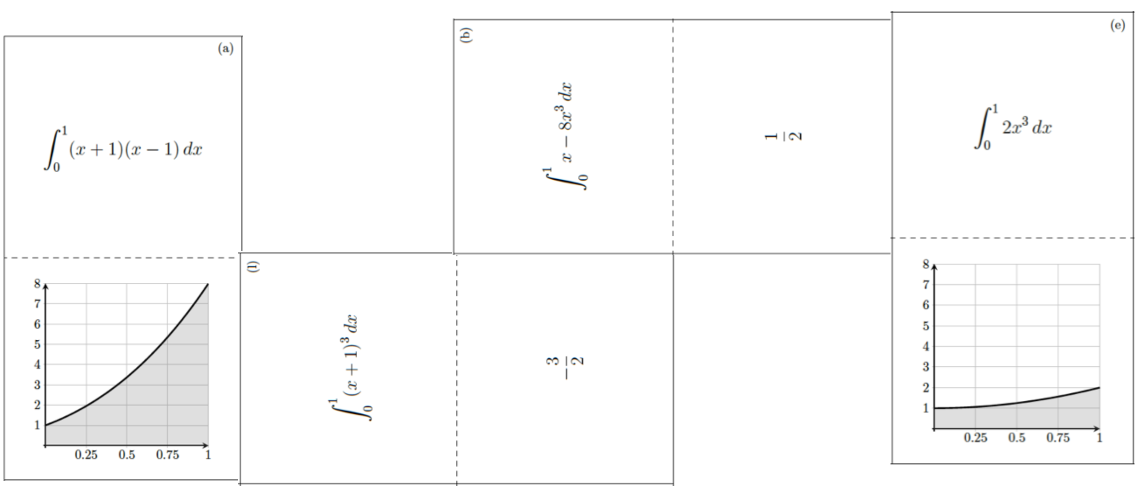

Figure 1: Partial solution of the Definite Integral Domino TACTivity

The other reason to design these TACTivities was that we found they required “low instructional overhead.” Often, calculus instructors are graduate students who have limited experience opportunities for professional development in student centered pedagogy. Even at universities where calculus is taught in large lectures there are usually a multitude of recitation

[3] Many resources similar to these have been reviewed, field tested, and published to a publicly available website: math.colorado.edu/activecalc

sections which are typically led by doctoral students. Calculus instructors typically have little experience learning the craft of teaching compared to that secondary mathematics teachers experience in their licensure program. Rather than being able to offer multiple courses to calculus instructors that are connected to field experiences, training at the university was necessarily limited to the weekly one-hour meetings for calculus instructors.

These activities, therefore, were designed to be easy to launch – i.e., they were somewhat intuitive for students as to how to proceed with minimal guidance from the instructor. As instructors used these TACTivities, and as student discussions about the representations emerged, instructors would hear and observe students' ideas and conceptions and use that information as they interacted with groups or facilitated a whole class debrief of the activity.

CALCS instrument. When the ALM RAC formed we recognized one of our primary drivers was students' dispositions towards mathematics. To change student persistence in calculus courses we needed to monitor any shifts in students' attitudes and conceptions of mathematics and what it means to engage in mathematical activity. After reviewing the options available for student mathematics surveys, we decided to use the Colorado Learning Attitudes about Science Survey (which had a mathematics specific version available). Over time as this survey was used we collected enough data to run several factor analyses which informed the inclusion, adaptation and deletion of prompts and thereby strengthened the assessment of several constructs. This adapted survey was renamed the Collegiate Active Learning Calculus Survey (CALCS) instrument and has four main components:

- student attitudes toward mathematics;
- perceptions of the pervasiveness of active learning in class;
- history of previous math courses and intent to take future math courses; and
- Student Assessment of Learning Gains, to serve as a common measure of student content learning that can span different courses and institutions.

The CALCS survey is now a primary data source for the ALM RAC, and all partners are expected to administer this survey at the beginning and the end of the semester. The University of Nebraska Lincoln has been conducting ongoing analysis of data received by partners to continue to monitor the quality of survey as it relates to the intended constructs measured.

Impacts of the ALM RAC

Several of our partners are showing simultaneous improvements to DFW rates and persistence rates in the P2C2 sequence. To date, the ALM RAC has grown from its original five universities to include the following fourteen partner institutions: Auburn University, Cal State Fullerton, Colorado State University, Florida International University, Fresno State University, University of Colorado Boulder, University of Hawaii-Manoa, University of Nebraska Lincoln, University of Nebraska Omaha, University of South Carolina, San Diego State University, Tuskegee University, West Virginia University and Western Michigan University. Given that our work focuses on changing the teaching of calculus by supporting departmental change, we find the scaling of our group nearly threefold to represent a significant impact on instructors and students. Since the P2C2 sequence involves high enrollment courses, the infusion of ALM in just Calculus 1 could impact over 1000 students each year for just one institution. If all partner institutions implement ALM throughout the P2C2 sequence, the potential number of students who could be impacted by the ALM RAC exceeds 40,000 students each year.

With respect to the Mathematics Teacher Education-Partnership, and the preparation of secondary mathematics teachers, data from the CALCS survey indicates a potential yield rate of 2% of calculus students who are interested in pursuing a teaching license, or approximately 800 students per year. Even though there may be various reasons that students' intentions may shift as they proceed from completing calculus to committing to a major, improving students' persistence rate for course completion and improving the quality of their undergraduate mathematics experience should have a positive impact on mathematics teacher preparation.

Other unexpected impacts of the ALM RAC include influence on other STEM disciplines as many students who complete calculus eventually pursue science or engineering majors, and possibly licensure pathways related to those disciplines. We have also learned of cases in which ALM instructional resources have been shared with science and engineering faculty, building local awareness of active learning initiatives and their potential benefit. Lastly, we know that high school and community college calculus are aware of our work and are using our resources to support ALM implementation in their classrooms.

Summary of Conference Activities

At the 2016 MTE-P Annual Conference we needed to accomplish several goals:

1. To decide on an approach to organize into sub-RACs given the growth of the ALM RAC;
2. To prepare proposals for hosting and arranging site visits to use available Helmsley funding;
3. To develop a list of needs to support local efforts, some which require funding;
4. To support data collection and analysis at new partner institutions; and
5. To discuss the relationship between the awarded NSF IUSE grant, SEMINAL, and the ongoing work of the ALM RAC.

Organizing into sub-RACs. To help manage the growth of the ALM RAC and provide sufficient feedback and support to the needs of specific institutions, we agreed that it was necessary to organize into smaller groups as sub RACs. After deliberating various ways to organize such groups we decided that it would be best to have three course specific groups:

pre-calculus, Calculus 1 and Calculus 2. Even though similar issues are encountered in each course, the curriculum expectations and student enrollment tend to be more similar within each course. The course sub-RACs have agreed to convene virtually every other month starting September 2016.

We also recognized that a permanent sub-RAC structure could limit the interaction between partners and so we also agreed that topical sub-RACs could be convened. Topics relevant to the needs of faculty would be proposed and facilitators would self-nominate to facilitate virtual meetings to discuss challenges and strategies used to address those challenges. To date five topical sub-RACs have been proposed:

- Understanding students' background and interests to support learning
- Lesson study in ALM Calculus I/II
- Professional development for GTA/GRAs
- Revising the CALCS student survey
- Supporting the collection of DFW and persistence data w/ proposals for a data dashboard

We plan to schedule topical sub-RAC meetings every other month starting October 2016.

Organizing site visits. To help the ALM RAC members better understand the similarities and differences among mathematics departments and local contexts, we committed to site visits in fall 2016 and spring 2017. During the conference we developed a table that described for each partner the faculty they should plan on visiting and what they might expect to observe. Our plan is to schedule at least four visits in fall 2016, and we recently constructed a Google Sheet that faculty modify at any time to support site visit planning.

List of local needs. Knowing that efforts are currently underway, we also proposed other options for allocating funds to support local initiatives – for example, jump starting a learning assistant program; partially fund a calculus coordinator; develop additional instructional resources, etc. Even though this is not how Helmsley funds were originally allocated we felt that it would be useful to outline other priorities for funding.

Data collection. The collection of student and instructor data is important to inform progress and necessary revisions to PDSA cycles. However, data collection requires approved IRB protocols and agreement on methods to support reliable data collection across institutions. We discussed how particular methods and incentives could be used to support higher response rates and shared previously approved IRB protocols and instruments to support local research.

Award of NSF IUSE grant. We were awarded a NSF IUSE grant, aka SEMINAL, to study the process of institutionalizing active learning in Pre-calculus through Calculus 2. The project will draw on institutional change research, research on productive undergraduate mathematics learning environments, and on the shared expertise of faculty to study the effect of institutional culture on mathematics teaching and learning in the P2C2 sequence within and across contexts. ALM RAC members will contribute to this work in multiple ways.

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MTE-Partnership
Solicitation for Participation in the
Active Learning in Mathematics RAC
April 18, 2016

Problem Addressed

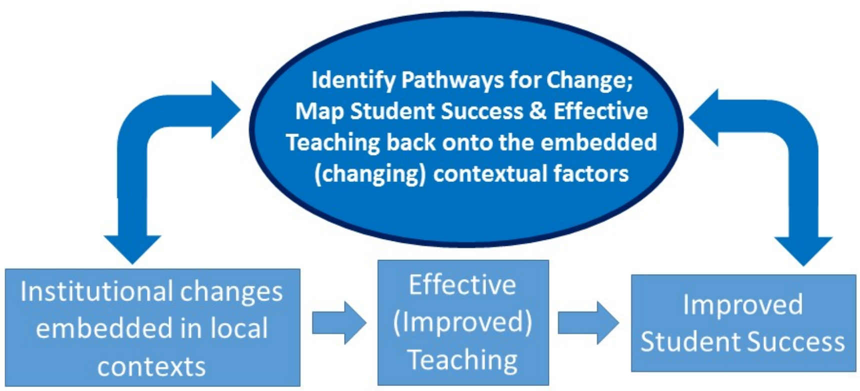
Student success in undergraduate mathematics has significant implications for whether they choose to continue into STEM majors and future related careers. Even for those students who do not choose to major in mathematics, science or engineering, success in entry-level undergraduate mathematics courses such as calculus can make or break their decision to persist in postsecondary education.

The Characteristics of Successful Programs in College Calculus (Bressoud, Carlson, Mesa, & Rasmussen, 2013) showed the percentage of students with grades of D, F or Withdraw ranged from an average of 25% at Ph.D.-granting universities to an average of 37% at regional comprehensive universities. We are committed to improving students' achievement in and dispositions towards mathematics through the use of models for Actively Learning Mathematics.

With respect to the MTEP Guiding Principles, the ALM RAC involves *Commitments by Institutions of Higher Education* through Institutional Focus, Disciplinary Partnerships, and Institutional Support for Faculty. The ALM RAC also addresses the guiding principle of *Candidates' Knowledge and Use of Mathematics* through future candidates' engagement in Mathematical Practices in introductory level undergraduate mathematics courses, to deepen their Knowledge of the Discipline.

General Approach

Our working theory of change is articulated in the following diagram:



The overarching goal is to improve student success with undergraduate mathematics, starting with the Pre-calculus through Calculus 2 sequence (P2C2). This is accomplished through effective teaching practices, which are supported by learning environments that are more conducive to student interaction, reasoning, and problem solving and the use of instructional resources to support ALM. Faculty buy-in and institutional leadership is developed to support Graduate Teaching Assistant training. Also, for many campuses, undergraduate learning assistants are used to support student work with group activities and enhance student engagement in mathematical activity.

Who We Are

Auburn University: Gary Martin, Ulrich Albrecht

Fresno State University: Lance Burger

University of Colorado Boulder: David Webb, Faan Tone Liu, Eric Stade, Robert Tubbs

University of Nebraska Lincoln: Wendy Smith, Judy Walker, Allan Donsig, Yvonne Lai

University of Nebraska Omaha: Angie Hodge, Janice Rech

University of South Carolina: Sean Yee

San Diego State University: Chris Rasmussen, Janet Bowers

Tuskegee University: Lauretta Garrett, Anna Tameru

West Virginia University: Vicki Seeley, Nicole Engelke, Matthew Campbell

Western Michigan University: Tabitha Mingus, Melinda Koelling

Current Progress

Over the past three years, we have worked collaboratively to improve instruction in introductory calculus courses. While the contexts across the ten campuses are quite different, requiring somewhat different approaches to implementing ALM, we have been able to learn from each other's efforts. We have exchanged and co-developed instructional resources, used common measures to document student dispositions, and have regularly discussed the local models used to support learning environments that are more conducive to ALM. At least three campuses adopted the "learning assistant" model used by Colorado, while West Virginia uses Graduate Teaching Assistants in a similar role. Discussions across campuses have helped to clarify the approaches used and have identified the critical role of institutional change in promoting ALM.

Opportunities for Engagement

We are currently utilizing resources from the Helmsley Foundation to coordinate planning meetings to share data collection efforts and develop a research agenda focused on understanding the process of institutional change. A collaborative research grant – Student Engagement in Mathematics through an Institutional Network for Active Learning (SEMINAL) – describes how we intend to better understand how to enact and support institutional change in undergraduate mathematics. SEMINAL will also support future efforts focused on increasing student success and persistence in the pre-Calculus to Calculus 2 (P2C2) sequence, and will promote adoption of ALM among MTEP institutions.

The Active Learning RAC is currently seeking additional partners who are interested in contributing to future research and products, including the use and revision of instructional resources, professional development materials, documented strategies to support instructional change, and the use and improvement of relevant measures to study the impact of these changes (full partner).

We also welcome partners who are interested in field-testing and implementing ALM resources and measures, without the full commitment of contributing to the Active Learning agenda or development of resources (participating partner).

The Mathematics of Doing, Understanding, Learning, and Educating for Secondary Schools[1]

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The Mathematics of Doing, Understanding, Learning, and Educating for Secondary Schools [MODULE(S^2)] Research Action Cluster (RAC) is focused on the development of prospective secondary mathematics teachers' (PSMTs') knowledge of mathematics content needed to support student learning. This focus addresses recommendations set forth in *The Mathematical Education of Teachers II* (Conference Board of the Mathematical Sciences [CBMS], 2012) for courses in secondary mathematics teacher preparation programs to provide opportunities for prospective teachers to "delve into the mathematics… while engaging in mathematical practice as described by the CCSS" (CBMS, 2012, p. 46). The work of the RAC aims to address the identified problem that undergraduate programs fail to lead teacher candidates to: a) deeply understand the mathematics they will actually teach and b) experience learning in a manner consistent with what will be expected of them as professional educators (Banilower et al., 2013).

In response to this problem, the MODULE(S^2) RAC has established the following objectives:

- Create twelve collaboratively designed modules aimed to develop PSMTs' mathematical knowledge for teaching algebra, geometry, modeling, and statistics in grades 6-12.
- Pilot and support the implementation of the modules.
- Revise the modules based on implementation data, instructor feedback, and PSMTs' work.
- Evaluate the effectiveness of modules with regards to their ability to develop PSMTs' mathematical knowledge for teaching.
- Disseminate the modules across multiple institutions, beginning with MTE-P institutions.

We adopted the Mathematical Knowledge for Teaching (MKT; Hill, Ball & Schilling, 2008) framework for our work. In this framework, subject matter knowledge for teaching

[1] The RAC Promo Sheet, presented during the opening of the conference to report on current activities of the RAC, can be found after the reference list.

Lawler, B. R., Ronau, R. N., & Mohr-Schroeder, M. J. (Eds.). (2016). *Proceedings of the fifth annual Mathematics Teacher Education Partnership conference*. Washington, DC: Association of Public Land-grant Universities.

mathematics includes the mathematics one teaches (Common Content Knowledge [CCK]), but it also includes knowing mathematics in a specialized way to meet the demands of teaching (Specialized Content Knowledge [SCK]) and the broader landscape of mathematics in which the mathematics one teaches is situated (Horizon Content Knowledge [HCK]). Pedagogical Content Knowledge (PCK) is also included in this framework, because it is specific to teaching mathematics. PCK includes three components in the MKT model: knowledge of how students conceive of particular content topics (Knowledge of Content and Students [KCS]), pedagogical principles for teaching specific content topics (Knowledge of Content and Teaching [KCT]), and knowledge of the curriculum resources available for the teaching of specific content and how to sequence their use to enhance student learning (Knowledge of Content and Curriculum [KCC]). Hill, Rowan and Ball (2005) showed that teachers' mathematical knowledge for teaching is positively correlated with student achievement, so growth of PSMTs' mathematical knowledge for teaching could have powerful effects on students' STEM achievement.

Current State of the Work

The proposed modules will be written with a common organizational structure. Materials for PSMTs will include activities, workbooks, excerpts from journals and secondary curricula, representations of practice, and homework sets. Materials for instructors will include instructor guides, assessment strategies, and teaching applications. Writing of modules is currently in various stages of production across the selected content areas.

In the 2014-2015 academic year, Emina Alibegovic and Alyson Lischka collaborated on writing and piloting three modules in geometry: (1) axiomatic systems, (2) rigid transformations, and (3) similarity and area. The modules include opportunities for PSMTs to analyze student work and depictions of classroom events through the Lesson*Sketch* platform (Herbst, Aaron, & Chieu, 2013). In the initial pilot year, participating PSMTs completed a pre- and post-test assessment of MKT (MKT-Geometry; Herbst & Kosko, 2012). Eighteen of the twenty-one students noted improvement in scores from pre-test to post-test. In Spring 2016, Alyson Lischka piloted revised materials and collected qualitative and quantitative data assessing the effectiveness of the materials in improving PSMTs' MKT. Pre- and post-test data was gathered using the Geometry Assessment for Secondary Teachers (Mohr-Schroeder, Ronau, Peters, Lee, & Bush, under review) to measure PSMTs' mathematical knowledge for teaching. The results indicated a statistically significant gain in geometric knowledge for teaching for the PSMTs. Preliminary analysis of qualitative data demonstrated a shift in PSMTs' ability to address specific mathematical ideas when responding to student thinking in a Lesson*Sketch* prompt. Further analysis is currently being conducted. Additional pilots are planned for the 2016-2017 school year.

The modeling writing team, Brynja Kohler and Cynthia Anhalt, has drafted three planned modules: (1) the modeling process, (2) classic models, and (3) in-depth modeling experience.

The project-based approach used in the modules, involving data gathering and creative model design activities, was inspired by labs that have been developed by Kohler and colleagues such as the Shrimp Diffusion Lab (Kohler, Swank, Haefner, & Powell, 2010), the Leaky Bucket Lab (Powell, Kohler, Haefner, & Bodily, 2012), and Coffee To Go (Kohler & Bruder, 2015).

Jason Aubrey and Yvonne Lai, have outlined three planned modules for Algebra on: (1) functions and relations, (2) complex numbers, and (3) ordered fields. An initial draft of the module on ordered fields focuses on properties of ordered fields which underlie the algebra curriculum in secondary mathematics.

In the 2014-2015 academic year, Andrew Ross and Stephanie Casey collaborated to write a statistics module addressing categorical association (including analysis of two-way tables, segmented bar graphs, and chi-squared randomization tests) and piloted it at 5 institutions. Analysis of the pre- and post-assessment data shows that the materials were effective at improving the participants' MKT for categorical association (Casey, Ross, Groth, & Zejnullahi, 2015; Casey, Zejnullahi, Wasserman, & Champion, 2015).

In addition to moving forward on writing and piloting modules, the MODULE(S^2) RAC has submitted an NSF proposal for an IUSE grant. Favorable comments were received from reviewers although the initial proposal was not funded. The team is currently working toward a resubmission of a revised proposal to fund the writing, analysis, and dissemination of this work. This project will not only develop materials that will increase PSMTs' MKT, it will also generate knowledge addressing important questions in the field of mathematics teacher education. The following questions are encompassed within the proposed future research assessing the effectiveness of the developed modules:

1. How do the MODULE(S^2) materials help PSMTs develop mathematical knowledge for teaching?
2. In what ways is the development of pre-service teachers' MKT related to their perception of content and skill at that content?
3. In what ways does pre-service teachers' MKT transfer between content context in which it was previously learned and new content contexts?
4. What are the necessary conditions to support implementation of the modules in current courses?

Moving Forward

Across the partners involved in the MODULE(S^2) RAC, reflections on existing piloted course materials have been positive. We have observed evidence that PSMTs increase their mathematical knowledge for teaching while learning mathematical content using the materials. We continue to revise and improve materials based on research findings. At many institutions, PSMTs complete College Geometry with the MODULE(S^2) materials prior to their Secondary

Mathematics Methods course. This is the case at Middle Tennessee State University, where it has been noted that mathematical knowledge for teaching that PSMTs gain in College Geometry serves as a vital foundation for discussions of practice in the methods course; PSMTs repeatedly point to the instruction in College Geometry as providing a connection to content they will teach while they concurrently engage in a deep exploration of geometric concepts.

Next steps include planned pilots of the geometry materials at additional MTE Partnership institutions and further work on materials in other content areas. This ongoing work will continue to contribute to the ways in which mathematics teacher educators can impact the mathematical knowledge for teaching developed among PSMTs at MTE partner institutions. Participation in the RAC's activities (including piloting) offers an opportunity for local partnerships to strengthen ties between members and stakeholders through the collaboration and local adaptation of the materials. We invite participating institutions to connect with the RAC and explore possible collaborations through writing, reviewing, and implementing the materials.

For More Information

- Alyson Lischka, Middle Tennessee State University, Alyson.Lischka@mtsu.edu
- Emina Alibegovic, Rowland Hall-St. Mark's School, eminaalibegovic@rowlandhall.org

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MTE-Partnership
Solicitation for Participation in the
MODULE(S)^2 RAC
April, 2016

Problem Addressed

During undergraduate study, prospective secondary mathematics teachers (PSMTs) do not always have the opportunity to build deep understanding of the mathematics they will be asked to teach. MODULE(S)^2 is concerned with developing mathematical knowledge and habits of mind for teaching for PSMTs.

We address *Candidates' Knowledge and Use of Mathematics* within the Teacher Candidate Knowledge, Skills and Dispositions section of the guiding principles as represented by the following indicators:

- Mathematical habits of mind
- Knowledge of the discipline
- Specialized knowledge of mathematics for teaching
- Nature of mathematics

General Approach

Our RAC aims to build communities among mathematicians, mathematics educators, and K-12 collaborators and work together to establish common content courses for mathematics teachers relevant to their professional needs. Because of the variety of needs and structures at different universities and teacher preparation programs, we have chosen to use a flexible format of creating course modules, each 3-5 weeks in length, that could be (a) used as a stand-alone mini course, (b) inserted into an existing course, or (c) combined to create one coherent course with the goal of creating a program in which all courses are carefully crafted to develop mathematical knowledge for teaching.

Our objectives are:

- Develop twelve collaboratively designed modules that focus on building a deep understanding of secondary mathematics themes identified in the CCSSM and the new CAEP accreditation standards.
- Investigate the impact of modules on PSMTs' opportunities to learn and readiness to teach school mathematics

Who We Are

- Geometry:
  - Emina Alibegovic, Department of Mathematics, University of Utah
  - Alyson Lischka, Department of Mathematical Sciences, Middle Tennessee State University
  - Taylor Haslam, Taylorsville High School, Granite District, Utah
- Modeling:
  - Brynja Kohler, Department of Mathematics and Statistics, Utah State University
  - Cynthia Anhalt, Department of Mathematics, University of Arizona
  - Brian Lawler, Mathematics Education, CSU San Marcos
- Statistics:
  - Stephanie Casey, Department of Mathematics, Eastern Michigan University
  - Andrew Ross, Department of Mathematics, Eastern Michigan University
  - Kady Schneiter, Department of Mathematics and Statistics, Utah State University
  - Joyce Smart, Logan High School, Logan City School District, Logan, Utah
- Algebra:
  - Jason Aubrey, Department of Mathematics, University of Arizona
  - Yvonne Lai, Department of Mathematics, University of Nebraska-Lincoln
- Master Editor:
  - Rachael Kenney, Department of Mathematics, Purdue University

Current Progress

- Geometry:
  - All modules completed
  - The course has been piloted at three institutions, two modules piloted separately at other institutions
  - In the process of editing and revising instructor and course materials
  - New pilots are scheduled for fall
- Modeling:
  - First module completed, first pilot scheduled for fall.
  - Modules 2 and 3 outlined, materials in development, ongoing research
- Statistics:
  - First module completed, and piloted at several institutions
  - Modules 2 and 3 outlined, materials in development, ongoing research
- Algebra:
  - First module completed, and piloted at several institutions
  - Modules 2 and 3 outlined, materials in development, ongoing research

Opportunities for Engagement

	Geometry	Modeling	Statistics	Algebra
Full partner				
Participating partner	Reviewing, editing, piloting*	Contributing, reviewing, editing, piloting*	Reviewing, editing, piloting*	Contributing, reviewing, editing, piloting*
Exploratory partner	Welcome	Welcome	Welcome	Welcome

* Partners involved with piloting will be asked to communicate frequently with the full partners. In addition, there will be data collection required for the purpose of course material improvement and revision.

Marketing to Attract Teacher Hopefuls (MATH) Conference Working Group Report[1]

Ed Dickey
University of South Carolina
edickey@mailbox.sc.edu

The MATH RAC convened on June 26 for the first of four working sessions during the MTE-P annual conference. RAC leader Ed Dickey had just provided the full audience of MTE-P attendees with a brief update of the work of the RAC over the past year. This update included the RAC's relation to the MTE-P Guiding Principles, in particular:

> **Guiding Principle 8. Student Recruitment, Selection, and Support**: The Teacher Preparation program actively recruits high-quality and diverse teacher candidates into the program and supports their success in completing the program as well as the specific problem the RAC is addressing:

- Secondary Mathematics Teacher Programs[2] (SMTPs) are not enrolling or graduating secondary mathematics teachers to satisfy the needs of U.S. middle and high schools
- Salary, stereo-types, job-satisfaction, career prestige, and the challenges of learning mathematics contribute to low enrollments in mathematics teacher preparation programs

The RAC's general approach for addressing the secondary mathematics teacher recruitment problem is based on the driver diagram, Figure 1, that was established at the founding of the RAC.

[1] The RAC Promo Sheet, presented during the opening of the conference to report on current activities of the RAC, can be found after the reference list.
[2] An SMTP is a program that includes a nationally accredited course of study housed at an institution of higher education that leads to licensure for teaching mathematics in grades 6-12.

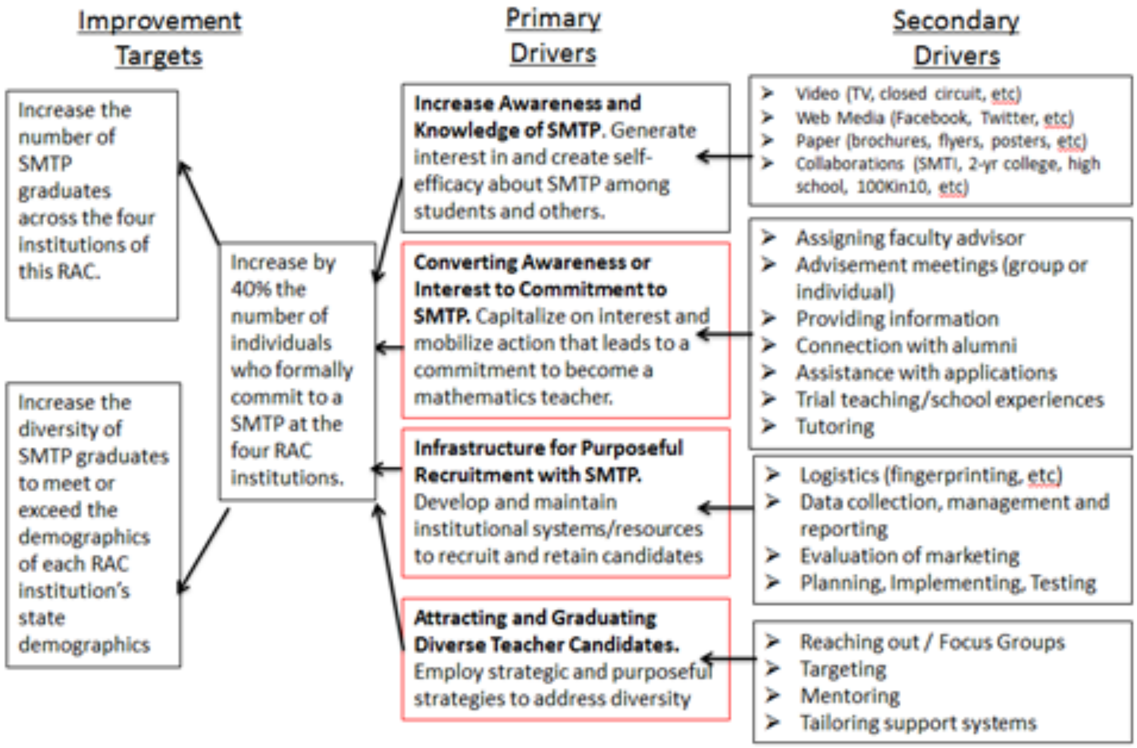


Figure 1. Driver diagram of the MATH RAC

RAC members attending the conference included those listed in Table 1, most of whom are seen in Figure 2.

Table 1.
MATH RAC Members That Attended the MTE-P 5 Conference

Name	Institution
Cynthia Anhalt	University of Arizona
Linda Venenciano	University of Hawai'i
Nancy Caukin	Middle Tennessee State University
Laurie Cavey & **Jan Smith**	Boise State University
Ed Dickey	University of South Carolina
Maria Fernandez	Florida International University
Dana Franz	Mississippi State University
Margaret Mohr-Schroeder (and Riley)	University of Kentucky
Rafaela Santa Cruz	San Diego State University
Carol Fry Bohlin	Fresno State University
Julie McNamara	CSU-East Bay
Cheryl Ordorica	CSU-Chico
Josh Males	Lincoln (NB) Public Schools
Amy Nebesniak	University of Nebraska at Kearney

Figure 2. Participants in the MATH RAC work groups during the MTE-P 5 conference.

Greg Chamblee (Georgia Southern University), Robin Hill (Association of State Supervisors of Mathematics), and Diana Suddreth (Utah State Office of Education), also participated in some of the work sessions. RAC members not attending the conference included Diana Barrett and Jim McKown (Hawai`i), Joe Champion (Boise State), Nadine Bezuk and Randy Philipp (San Diego State), Kathy Hann and Julia Olkin (Cal State East Bay), and Cheryl Roddick (San José State).

The RAC reviewed its progress to date that included the completion and dissemination of the **Secondary Mathematics Teachers Recruitment Campaign Implementation Guide** that was featured and described by Ed Dickey as part of his opening keynote address at the January 2016 meeting of the Association of Mathematics Teacher Educators. The Guide is posted for general use by teacher educators at bit.ly/MATHImplGuide.

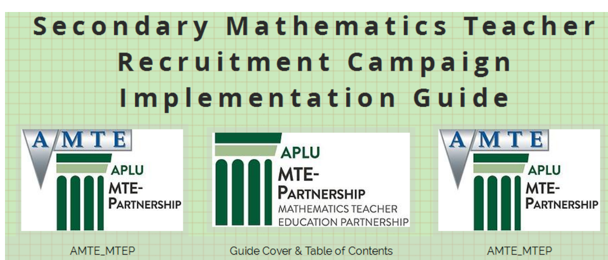


Figure 3. Format of the website hosting the Secondary Mathematics Teachers Recruitment Campaign Implementation Guide.

Many of the RAC's Plan, Do, Study, Act (PDSA) cycles are documented on a Padlet site that includes numerous products tied to the different interventions conducted over the past two years by RAC member institutions. The Padlet site is available at padlet.com/ed_dickey/vhle4gisbq82.

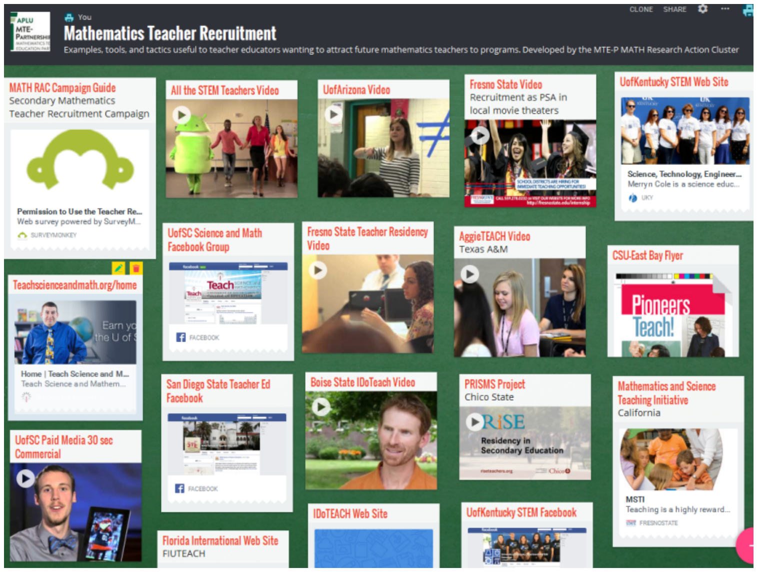


Figure 4. Format of the Padlet website reporting products of the MATH RAC.

The plan for the conference RAC work sessions was to first review the PDSA work at each site, then discuss future directions or initiatives for the RAC with attention to both identifying funding to support recruitment work and research and to address the MTE-P commitment to equity and social justice.

The second and part of the third working sessions on June 27 included brief presentations from each RAC member about current and past PDSAs. These were supported by a PowerPoint presentation complied and distributed to attending RAC members and are summarized briefly as follows:

- **Arizona**: After School and Tutoring programs, undergraduate Teaching Assistant Program, Noyce Seminars and recruitment efforts that include high school visits, orientations, career fairs, posters brochures, web site development and program video. More information including video at smep.math.arizona.edu.
- **Boise State**: completion of web site and several recruitment and program videos as part of the IDoTeach program. More information including videos at idoteach.boisestate.edu.
- **Florida International**; Student orientations through advising and resources fairs, recruitment courses, personalized email to all STEM majors, math/science course visits, STEM advisors briefings, web site development, open houses, Educators Rising Conference and high school events, internships. Survey and data collection on all strategies. More information at fiuteach.fiu.edu.
- **Kentucky**: continued social media efforts through Facebook, retention efforts through #IamAWomanInSTEM, NSF Showcase video: stemforall2016.videohall.com/presentations/815, working with newly hired recruiter and statewide STEM Education Center. More information at education.uky.edu/stem.

- **Mississippi State**: focused on data gathering that documented critical shortage of science and mathematics teachers in rural areas of state. University and College of Education efforts around #STATEPROUD campaign that addresses teacher preparation.
- **California State East Bay**: development of flyers and posters used throughout campus and community, with Pioneers Teach! Branding, meeting with undergraduate organizations, personal message to all applicants. More information at csueastbay.edu/ted.
- **Chico State**: completed first marketing campaign (described below) and beginning plans for second campaign. Graduate fairs and diversity forums, partner with New Media Agency for video production, and ads. Will use YouTube and Pandora. Expand to Sacramento area. Developing radio, movie theatre PSAs and flyers. More information at www.csuchico.edu/soe/rise
- **Fresno State**: leading Mathematics & Science Teacher Initiative (MSTI) that includes support for entire California State System in recruitment: conference travel support, early field experiences, interactive workshops, advisement, fee waivers for methods courses, stipends for student. Work with Fresno Teacher Residency Program including web site development, social media, open houses, direct emails, and video used as PSA in movie theaters and available at vimeo.com/114188236. More information at www.fresnostate.edu/kremen/teachmathscience.
- **San Diego State**: Social media presence through Facebook at www.facebook.com/SDSUSTE/?fref=ts.
- **Middle Tennessee State**: presenting at freshman mathematics and science classes, open house, advertising on campus TV, posters in science and mathematics buildings. Developing recruitment video. More info at www.mtsu.edu/mteach.
- **South Carolina**: completion of multifaceted recruitment campaign that include TV commercial, ambassadors program, Social Media effort with All the STEM Teachers Video and web site development. More information at teachscienceandmath.org/home and Beyonce video at youtu.be/i60KEyHtwgA. Facebook site at www.facebook.com/teachscienceandmath.

In addition to the work session presentations, two RAC members provided 30-minute Research Reports as part of a set of breakout sessions on June 27. Cheryl Ordorica of Chico State presented her work on the **CSU Chico Program RiSE: Analysis of the First Recruitment Cycle**. Cheryl described her project's recruitment efforts and data collection for Promoting Rural Improvement in Secondary Mathematics and Science (PRISMS), which includes the Residency in Secondary Education program. Her presentation highlighted the analytical tools tied to the project web site and social media strategies described in the Implementation Guide. Linda Venenciano spoke on the Mobilizing Efforts of the MTE-P Hui in Hawai`i describing the initiative's recruitment efforts tied the interest of indigenous peoples and with attention to ethnomathematics of interest to Hawai`ian teacher and learners.

In the third work session, RAC members determined that new efforts must be initiated to measure and document the impact of the different recruitment interventions employed by RAC members. The group assessed that significant progress has been achieved in understanding and creating recruitment strategies and now more effort and thought must be given to the assessment of how and to what degree the interventions work. To this end and as part of its final meeting on June 28, the group committed to gathering and analyzing data gathered through the MTE-P Hub from all partnership members to assess the current status of secondary mathematics teacher recruitment among partnership teams and to create a summary table for past PDSA activities that expands the documentation available through the Padlet site. The summary table will include more details on the PDSAs and also include an assessment of the impact (green representing positive gains, yellow indicating inconclusive, and red suggesting the intervention was not effective). The table will allow for documentation of future interventions. The data analysis will include particular attention to assessing progress toward recruiting diverse teacher candidates. Table 2 provides a preliminary draft of the summary table.

Table 2.
Proposed Template to Summarize previous PDSA activities conducted in the MATH RAC

Recruitment Strategy / Intervention	MATH RAC Institution	Brief Description	Link to Resource(s)	Impact or Results
Call to Action: TV Commercial on STEM Teaching	University of South Carolina	30 second commercial to inform about UofSC commitment to STEM teaching and to send view to web site for more information	youtu.be/oxzEdcFn62E	Significant web traffic after each broadcast.

Recruitment strategies or interventions will include:

- *Calls to Action:* phone, flyer, mailing, poster, web site, online video, TV commercial video, PSA video, radio, billboard, open house
- *Cultivation:* classroom observation, school visit, tutoring, teaching enactment
- *Conversion:* advisement meeting, faculty interview

The RAC members decided to use the Trelliscience.org online community to share recruitment tools that are under development within the newly created MATH RAC group. As tools begin to be used, they will be made available to the MTE-P group within Trellis as will the summary table. This will allow both the RAC and Partnership groups to provide appropriate feedback and support. As products mature, they will be posted on Padlet for a broader audience.

Funding through the National Science Foundation Noyce program was discussed. Several members participated in the June Webinar on the new solicitation but determined that the expectations for Track 4 research funding are now focusing more narrowly on teacher effectiveness, persistence, or retention in high-need education agencies, which the members determined to be incompatible with current RAC efforts. The RAC will not submit a proposal for the September 2016 cycle and will consider other funding options for the future.

The RAC members committed to participating in the Purposeful Recruitment, Exploration, and Preparation (PREP) Initiative begun among the California State University MTE-P members. The initiative includes a process of identifying promising future secondary mathematics teachers through mathematics and other university faculty members then inviting them to participate in a "celebration of teaching" event designed to include both working mathematics students and secondary school age students so as to provide the promising future teacher with a positive experience that might cultivate a commitment to teaching. Particular attention will be given to identifying promising teachers of color and the mathematics activities will be selected to address how mathematics might serve to impact or inform social justice issues.

At the closing session of the MTE-P conference, Ed Dickey presented a summary of the work accomplished and plans for the coming year to the attendees from all partnership teams.

Solicitation for Participation in the

MATH: Marketing to Attract Teacher Hopefuls RAC

April, 2016

Problem Addressed

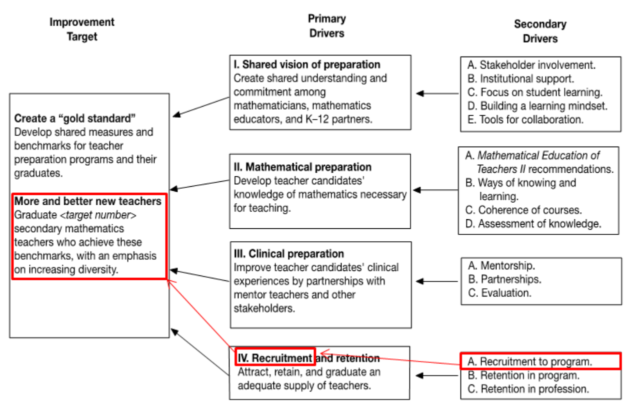
Guiding Principle 8. Student Recruitment, Selection, and Support: The Teacher Preparation program actively recruits high-quality and diverse teacher candidates into the program and supports their success in completing the program.

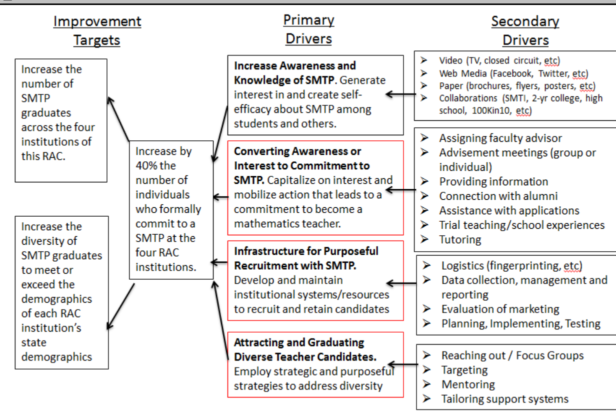
Problem:

- Secondary Mathematics Teacher Programs* (SMTPs) are not enrolling or graduating secondary mathematics teachers to satisfy the needs of U.S. middle and high schools
- Salary, stereo-types, job-satisfaction, career prestige, and the challenges of learning mathematics contribute to low enrollments in mathematics teacher preparation programs

* An SMTP is a program that includes a nationally accredited course of study housed at an institution of higher education that leads to licensure for teaching mathematics in grades 6-12.

General Approach





- Provide models for developing and launching purposeful and sustained marketing campaign that rebrands teaching to appeal to STEM majors
- Include adaptions for programs focusing on undergraduates, UTeach, alternative pathways, and other models
- Identify critical experiences in mathematics and clinical work that impact recruitment and retention

Who We Are

Cynthia Anhalt, University of Arizona, & **Maria Fernandez**, Florida International University	**Jennifer Whitfield,** Texas A&M University
Diane Barrett, Jim McKown & Linda Venenciano, University of Hawaii	**Nadine Bezuk, Randy Philipp & Rafaela Santa Cruz**, San Diego State
Nancy Caukin, Middle Tennessee State	**Carol Fry Bohlin**, Fresno State University
Laurie Cavey, Joe Champion & Jan Smith, Boise State	**Kathy Hann, Julie McNamara & Julia Olkin**, CSU-East Bay & **Cheryl Roddick**, San Jose State
Ed Dickey, University of South Carolina	**Cheryl Ordorica,** CSU-Chico
Dana Franz, Mississippi State University	**Sofia Vicuna**, CSU-Monterey Bay
Margaret Mohr-Schroeder, U of Kentucky	

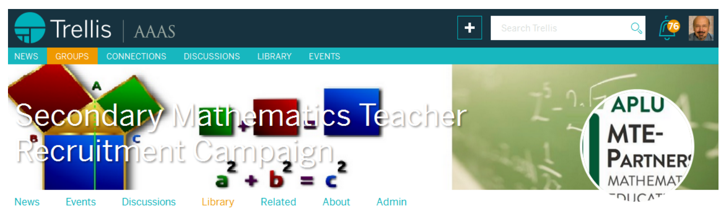
Current Progress

Each partner is implementing ***Plan Do Study Act*** cycles tied to recruitment and using measures of program inquires and enrollments to monitor impact. Boise State, Middle Tennessee State, and FIU are addressing UTeach replication recruitment efforts. Arizona, Kentucky, Mississippi State, Texas A&M, and UofSC as well as the California State System campuses are implementing various strategies and recruitment tactics tied to their own programs.   Efforts include website development, class meetings, posters, social media efforts and videos. Sample partner websites are at

- U of Arizona: **SMEP**: http://math.arizona.edu/~smep/
- Boise State Univ, **IDoTeach**: http://idoteach.boisestate.edu/
- Florida International Univ, **FIUTeach**: http://fiuteach.fiu.edu/
- University of Kentucky, **STEM Dept**: https://education.uky.edu/stem/
- Mississippi State: **CISE**: http://www.cise.msstate.edu/
- Texas A&M Univ, **AggieTeach**: http://aggieteach.tamu.edu/index.shtml
- Univ of South Carolina**, TeachScienceandMath**: http://teachscienceandmath.org

The RAC has created and disseminates a 9-module **Secondary Mathematics Teacher Recruitment Campaign Implementation Guide** available within Trellis and at ***http://bit.ly/MATHImplGuide*** .

- Module 1 Teacher Recruitment Campaign Overview
- Module 2 Campaign Planning
- Module 3 Campaign Research
- Module 4 Branding
- Module 5 Social Media
- Module 6 Public Relations
- Module 7 Paid Broadcast Media
- Module 8 Web Site Identity
- Module 9 Lessons Learned/Evaluation



RAC members share **recruitment tools** (flyers, posters, videos, websites, etc) at *http://padlet.com/ed_dickey/vhle4gisbq82*

The RAC is collaborating with the STRIDES RAC to implement the **Purposeful Recruitment, Exploration, and Preparation (PREP) Initiative** in Fall 2016.

The RAC is preparing a **proposal** to anticipated **NSF Noyce Track 4** solicitation.

Opportunities for Engagement

- As a full partner commit to implementing marketing tactics and share strategies, results, and data with RAC members. As participating partners, join in periodic conference calls to learn about activities and share information as appropriate.
- Review and provide feedback to improve the Implementation Guide.
- Participate in the PREP Initiative planning and implementation.
- Collaborate and consider participating in the NSF Noyce Proposal that will be submitted by in Fall 2016.
- Explore and implement strategies to diversify pool of teacher candidates and more effectively impact issues of equity and social justice in school settings.
- Participate in the building of a Recruitment Resources Collection with the new MTEP online communication and collaborative work platform with the AAAS Trellis site: http://www.trelliscience.com

Secondary Teacher Retention & Induction in Diverse Educational Settings[1]

Link to Promo Sheet

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Overview of the STRIDES RAC Work to Date

Half of all teachers leave the profession within the first five years. This rate is even higher for mathematics positions in high poverty schools (Fantilli & McDougall, 2009; Goldring et al., 2014). Furthermore, with half of all current teachers in the U.S. retiring in the next five years (Foster, 2010), enrollment in teacher preparation programs declining, and teacher turnover costing America $7.3 billion annually (National Math + Science Initiative, 2013), the mathematics teaching crisis is of major proportion. This crisis leads to many underprepared mathematics teachers and has a profound effect on how well prepared our students are to be successful in high school, college and beyond. Experts agree that addressing the mathematics teaching crisis meaningfully will require building a more cohesive system of teacher preparation, support, and development (Mehta, Theisen-Homer, Braslow, & Lopatin 2015).

The Secondary Teacher Retention & Induction in Diverse Educational Settings (STRIDES) Research Action Cluster (RAC) addresses Mathematics Teacher Education Partnership (MTE-P) Guiding Principle 8: Student Recruitment, Selection, and Support. Teacher preparation programs actively recruit high quality and diverse teacher candidates and monitor/support them as they complete their programs. Since the inception of MTE-P, the national problem of retaining secondary mathematics teachers within the profession has been a priority. This priority led to a proposal to form a RAC focused on retention at the 2013 MTE-P Annual Conference, but was not acted upon in order to focus first on recruitment. The Marketing for Attracting Teacher Hopefuls (MATH) RAC was formed with this charge. A few years later, the recruitment effort was rekindled, and the STRIDES RAC began its work by creating the driver

[1] The RAC Promo Sheet, presented during the opening of the conference to report on current activities of the RAC, can be found after the reference list.

diagram shown in Figure 1, based on a review of recent literature on retention. The aim statement and drivers include support for early career teachers and Professional Learning Communities, and call for the examination of school structures and professional pathways to support/retain teachers.

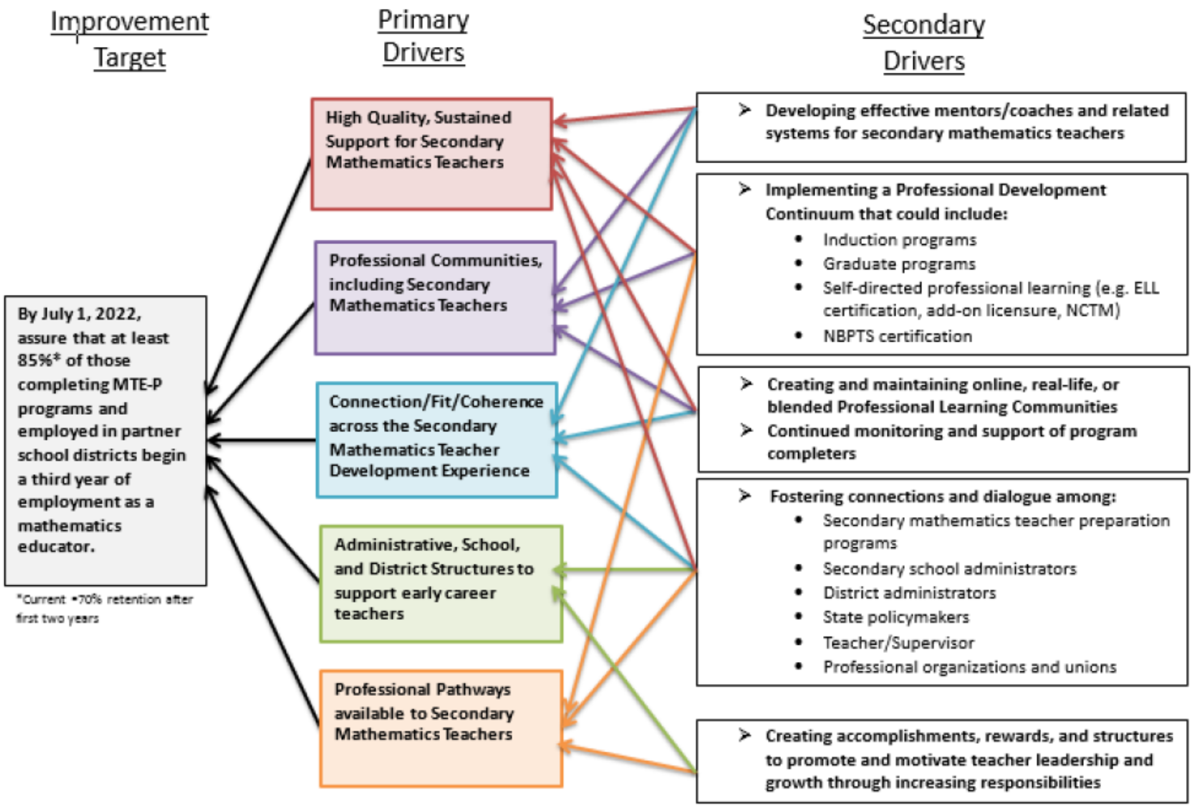

Figure 1. STRIDES driver diagram.

Members of STRIDES decided early on that the work of the RAC must focus on understanding and providing support for both pre-service and early in-service teachers, given the significance of a cohesive continuum of professional learning on teacher growth and retention. Thus, to launch early initiatives aimed at improving teacher retention rates, STRIDES members designed a survey in summer 2015 to gather preliminary data on the nature and quality of professional support for pre-service, 1st, 2nd, and 3rd year teachers. Specific research questions guiding this effort were: What is the perceived scope, nature and impact of professional support for early career mathematics teachers?; and How does this (a) change as teachers progress in their teaching career and (b) relate to how likely it is a teacher will remain teaching? Researchers from thirteen institutions and secondary mathematics teachers from four school districts designed the pilot survey, called "Reflection on Professional Activities." This survey was created through an iterative design and vetting process, having stemmed from a discussion centered on research-based reasons that teachers leave the field.

The survey asked participants to specify activities that have helped them grow professionally, and the degree to which these activities were worthwhile to them, allowing STRIDES to better understand the degree to which early-career mathematics teachers are being supported by professional learning opportunities, professional learning communities, and administrators. Also, instructional context (i.e. public, private, etc.) data was collected, as well as whether the early service teachers serve students from special populations (i.e. special education, English Language Learner, gifted). Participant estimations regarding the degree that specific professional development activities changed these teachers' practices, as well as the level of "inspiration" these activities invoked, were surveyed, allowing researchers to discern connections between these two measures. Qualitative responses allowed survey participants to provide additional details regarding their support systems. Finally, the degree that the participants felt that their administrators support them professionally was measured, including support in specific areas (e.g. assessment, instruction, curriculum, classroom management, collegial collaboration and course assignments/loads).

Work of the STRIDES RAC at the 2016 Annual Meeting

At the Fifth Annual MTE-P Conference in Georgia, STRIDES members analyzed data from the pilot survey with two goals: (1) Create a revised survey that could be sent to early-career teachers across the MTE-P network 3-4 times in the 2017-18 year to understand professional support, and (2) To develop intervention(s) targeting professional learning and support for early-career teachers to launch in August 2016. The group analyzed pilot survey data with respect to respondents' (N=66) reports of professional learning and support, and the impact on their teaching. Further, a subset of those surveyed responded twice (N=19) allowing for consideration of the change in these reports over time.

To analyze the data, STRIDES members split into three groups, each with a distinct lens: nature and impact of professional learning activities, nature and impact of participation in professional communities, and the nature and impact of support from administrators. Each group examined qualitative and quantitative responses, summarized key themes and questions for the group, and posted key inferences on posters around the room. Based on each inference, individual RAC members brainstormed ways we might revise the survey for full implementation in Fall 2016 and ways we might make early career teachers' professional learning and support more effective. From this collection of ideas the group distilled three, key change ideas: (1) the need for long-term, collaborative groups for early-career teachers to participate in, (2) a clearer role of site-based administrators and colleagues in supporting these collaborative groups, and (3) the need to train and support the mentors supporting these early-career teachers.

STRIDES RAC members self-selected into one of these three groups to create PDSA cycles that would guide early interventions in Fall 2016. The change idea and questions each group will begin to address are provided in Table 1.

Table 1
Change idea and guiding questions.

Change Idea	Description of Change Idea	What We Want to Learn
1. Long-Term Collaborative Groups for Early Career Teachers	Teacher collaborative groups that focus sustained attention on one teaching practice for early career teachers can support a sense of professionalism and professional improvement for early career teachers.	*How can collaborative teacher groups be supported to engage in sustained attention to a particular teaching practice that early career teachers can grow in?* *How does participation in a collaborative group develop a sense of accomplishment in relation to the selected practice?* *What structure of collaborative group creates a positive perception about their profession and future professional trajectory?*
2. Role of Administrators and Site-Based Colleagues	Support administrators by creating a common vision and using strategies to reinforce retention of early career mathematics educators.	*What targeted supports for administrators' impact teacher retention?*
3. Training & Supporting Teacher Mentors	Does training mentors affect teacher retention?	*Can mentor teachers use the learning cycle (see below) to facilitate early career (pre-service through 3rd) teachers enacting the 8 core teaching practices defined by NCTM?*

Conclusion

Two primary conclusions of the STRIDES RAC from the 2016 annual meeting were that supporting early-career mathematics teacher retention will involve a cohesive effort across teachers' entrance into and early years in the profession, and the preparation and support provided to new mathematics teachers by teacher educators, mentors, coaches, administrators, and colleagues must be more cohesive. The three change ideas for better supporting early career teachers (see Table 1) distilled from the pilot data are symbiotic; early-career mathematics teachers need to participate in professional communities composed of other new teachers (Change Idea 1), need targeted support from administrators, colleagues, and mentors (Change Idea 2), and these mentors need training on mentoring that supports mathematics teacher development and retention (Change Idea 3). Members of the STRIDES RAC will work during 2016-17 in smaller groups to implement PDSA cycles based on these change ideas at their respective institutions. Additionally, a RAC subcommittee is revising the survey and disseminating to a larger participant pool three times during the 2016-2017 academic year. The revised survey will inform STRIDES members as they engage in the PDSA cycles that target retention efforts for secondary mathematics teachers.

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MTE-Partnership

Solicitation for Participation in the planned

STRIDES: Secondary Teacher Retention & Induction in Diverse Educational Settings

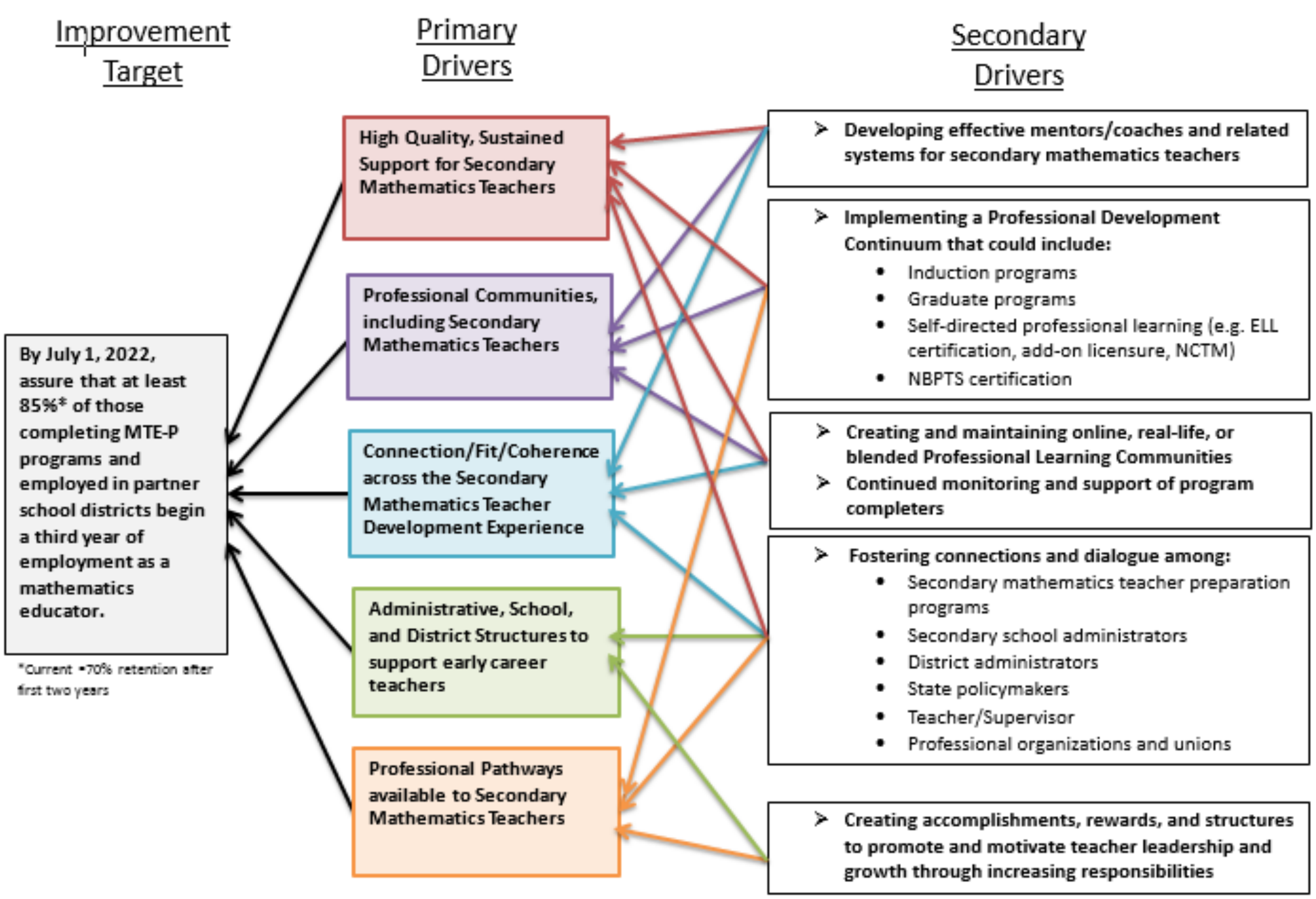
April, 2016

Problem Addressed

Guiding Principle 8: **Student Recruitment, Selection, and Support**
The teacher preparation program actively recruits high-quality and diverse teacher candidates into the program, and monitors and supports their success in completing the program.

Since the inception of MTE-P, the national problem of retaining secondary mathematics teachers within the profession has been a priority. A RAC on retention was proposed at the 2013 Conference, but not implemented because recruitment was determined to be a higher priority at the time. From review of the earlier White Paper, the previous RAC proposal, and more recent literature on retention, the driver diagram below is proposed with an aim statement and drivers that include support for early career teachers, PLCs, and the need to examine school structures and professional pathways.

General Approach



Who We Are (Current Working Group)

- **APLU**
  - Howard Gobstein
- **Auburn University**
  - Gary Martin
- **California State University**
  - Nancy Barker
  - Eric Hsu
  - James Martinez (co-leader)
  - Fred Uy
- **East Central Texas**
  - Laura Wilding
  - Jennifer Whitfield
- **Georgia State University**
  - Pier Junor Clarke
- **South Dakota**
  - Nicol Reiner
  - Jami Stone
- **Trellis Education**
  - Megan W. Taylor (co-leader)
- **University of Cincinatti**
  - Bob Ranau
- **University of Kentucky**
  - Lisa Amick (co-leader)
  - Craig Schroeder
- **University of South Carolina**
  - Ed Dickey (initial organizer)

Current Progress

After a recent survey of partnership members, a significant interest in teacher retention and induction was assessed, so a working group made up of partners expressing a strong interest in the topic was formed. The working group reviewed prior literature and recommendations to analyze the retention problem in the context of Secondary Mathematics Teachers, to understand the current problem space, and devise a new driver diagram.

From the driver diagram, a research question was selected, "What is the perceived scope, nature and impact of professional support for early career mathematics teachers, and how does this (a) change as teachers progress in their teaching career and (b) relate to how likely it is a teacher will remain teaching?" With this question in mind, researchers from thirteen institutions nationwide and secondary mathematics teachers from four school districts, all part of the MTE-P, designed a pilot survey called "Reflection on Professional Activities." This survey was created through an iterative design and vetting process that extended from the fall of 2014 throughout early 2016. The survey stemmed from a discussion centered on research based reasons that teachers leave the field. A brainstorming session followed the discussion, clustering those reasons into categories, and those categories eventually became the main components of the survey (professional activities, support, job satisfaction, etc.). This survey was edited numerous times during face to face discussions of the research group, virtual meetings, and finally feedback from early career teachers who will soon be completing the survey. The current data collection tool is a 20-item survey asking participants – secondary mathematics teachers in their first, second, or third year of teaching – to reflect on the degree to which the professional learning activities and communities they participate in (e.g., working with a mentor, attending a professional conference, being a Noyce Scholar) increases their enthusiasm for teaching mathematics and influences their ability to facilitate student learning. Additionally, participants are asked to describe the role of administrators, universities, and school structures (e.g., teaching load) on these self-reports, and their satisfaction with teaching and likelihood to continue teaching. The survey was recently distributed nationwide in March of 2016 to begin the pilot study. Changes and refinements will continue to be made after the first round of preliminary data is collected to improve the quality and functionality of the survey.

In order to better understand the degree to which early-career mathematics teachers are being supported by: 1) professional development, 2) professional learning communities and 3) administrators, the survey allows participants to specify activities that have helped them grow professionally, and the degree to which these activities were worthwhile to them. Additionally, since the survey is longitudinal, responses can be measured over time, allowing the researchers to understand how these teachers are supported throughout their early service (preservice, 1st, 2nd, or 3rd) years. This measure will allow for correlations to be explored regarding the level of professional support these teachers receive based on years of teaching experience. Also, instructional context (i.e. public, private, etc.) data will be collected, as well as whether the early service teachers have students from special populations (i.e. special education, English Language Learner, gifted) in their classrooms. Surveyed early-career teachers will provide data regarding the level of support they receive from a range of professional learning communities (PLCs), including on- and off-site groups, professional organizations (e.g. NCTM), and on-line groups. Participant estimations regarding the degree that specific professional development activities changed these teachers' practices, as well as the level of "inspiration" these activities invoked, will be surveyed, allowing researchers to discern connections between these two measures. Qualitative responses are provided in the survey which allows survey participants to provide additional details regarding their most meaningful PLCs. Finally, the degree that the participants feel that their administrators support them professionally is measured, including specific areas (e.g. assessment, instruction, curriculum, classroom management, collegial collaboration and course assignments/loads). The survey ends with an estimation of: 1) their overall level of satisfaction in their teaching, 2) whether they would choose the profession again knowing what they have learned so far, and 3) how long they plan to remain in the teaching profession.

Opportunities for Engagement

In spring 2016, each, current member of the STRIDES RAC sent the pilot survey to a few, select early career teachers, with a solicitation to complete it twice: March and June. This pilot data will be analyzed by the STRIDES RAC working group in the summer annual meeting to (a) iterate the survey for longitudinal use, (b) make initial hypotheses about the kinds of professional learning activities early service teachers in our partnership are engaging in and and the impact of these activities on their practice, and (c) design initial interventions to launch in fall 2016. It is the goal of the STRIDES RAC to assure that, by July 1, 2022 at least 85% of the program's early-service teachers employed in partner school districts begin a third year of employment as mathematics educators. With this goal in mind, it is imperative that data from the STRIDES survey be used to design interventions that support the development of pathways for teachers to enter and thrive in the teaching profession. These pathways will be locally defined by MTE-P schools and their district offices which will support early career teachers in their professional growth. For example, one pathway may provide access to a variety of roles for teachers in the program to provide professional growth opportunities at their schools, reducing the possibility of early departure. The intent is that all prescribed interventions follow a PDSA (i.e. Plan, Do, Study, Act) cycle, so that measures are recursively re-defined to better suit individual early-career teacher needs. Future ramifications of implementing STRIDES interventions to support the program's early-career teachers include: 1) establishment of a Network Improvement Community (NIC) model for collaboration-based support of mathematics teachers, 2) documentation of PDSA cycle effectiveness for specific support pathways, and 3) the development of a specific data-gathering instrument for researchers to use/modify for future studies.

RESEARCH PRESENTATIONS

Existing Mathematics Teaching Practices at an HBCU: Foundations for Teacher Preparation

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The Mathematics Teacher Education Partnership (MTE-P) seeks to transform the preparation of secondary mathematics teachers through several avenues of research and development. One of those avenues is being pursued by a research community supported by MTE-P that is known as the Active Learning Mathematics Research Action Cluster (ALM-RAC). Active learning involves a student-centered pedagogy in which students are encouraged to reason about thought-provoking problems (Smith, 2015). The goal is to raise student thinking to higher levels of Bloom's taxonomy (Krathwohl, 2002) in settings that encourage them to discuss mathematics with each other and to communicate about and defend their mathematical thinking—to be "active" mentally and socially in the lesson and in the classroom learning community rather than to be passively listening to a lecture (Diederich, 2010; Smith, 2015).

Higher-level of thinking is thinking that happens in the analysis, synthesis, and evaluation of a topic (Teach For America, 2011). Why do we want students engage in higher-level thinking? We would like students to remember mathematical ideas longer and more clearly. If students engage in higher-level thinking, they can have an increased ability to retain and apply mathematical knowledge (Garrett, 2014; NCTM, 2009). Consider the difference between memorizing multiplication tables and the deeper understanding that comes from connecting those operations to different ways of thinking such as an area model (NCTM, 2000). Such connections build a web of understanding that helps students access and use knowledge (Van de Walle, Karp, & Bay Williams, 2015).

The qualities of assessments used in mathematics courses are connected to the type of learning students will experience as well as the type of instruction. In the traditional lecture, students typically select an answer or recall information to complete an assessment. An assessment aligned with higher-level thinking is essential if students are expected to engage in such thinking in different classroom and assignment tasks. An instructor can identify the task that needs to be mastered and then a curriculum can be developed that will enable students to perform those tasks well (McDonald, 1992).

Theoretical Foundation: The Exam Characterization Framework

The *Exam Characterization Framework* (ECF) was developed as part of the Mathematical Association of America's efforts to provide empirical evidence for best practices in college mathematics instruction (Tallman, Carlson, Bressoud, & Pearson, 2016). In their efforts to characterize the nature of college Calculus 1 final exams, Tallman et al. formulated their own evaluation framework, the ECF, following an extensive review of existing frameworks and associated literature. They constructed their framework through "12 cycles of . . . coding exam items [on 5 Calculus I final exams,] refining [the] characterization of ECF constructs and recoding items" (p. 4).

The Framework. This developmental work resulted in three "item attributes" that are used to describe the qualities of exam items and thereby describe the qualities of the exam (Tallman et al., 2016, p. 7). *Item orientation* refers to the type of thinking that is needed for each exam item. *Item representation* refers to the type of representations present in the statement of the problem as well as the type of representations needed to solve the problem. *Item format* refers to whether or not the item is multiple choice, short answer, or a broad open-ended problem and whether or not the item requires an explanation.

Item orientation was broken down into seven levels. In their study, Tallman et al. (2016) found that only the first five levels were present in the Calculus 1 final exams they examined. They provided exam item examples in their report for each of the first five levels to facilitate the use of the framework by those wishing to characterize the level of cognitive demand present in examinations. Those first five levels, *remember, recall and apply procedure, understand, apply understanding,* and *analyze* are described in Table 1 and examples given of some of the behaviors that will be expected of students from those types of exam items. Level six, not found in the exams Tallman et al., looked at, was *evaluate,* which involves "mak[ing] judgments . . . checking and critiquing" (p. 9). Level seven, also not found, was *create,* which involves assembling, producing, generating and planning using mathematical ideas in ways that create new patterns. Levels five, six, and seven were informed by Krathwohl's (2002) discussion of Bloom's Taxonomy.

Their Study. Once they had a useful framework, Tallman et al. (2016) examined a sample of 150 Calculus final exams randomly drawn from 253 used during the 2010-2011 academic year at 253 different universities. The sample of 150 was comprised of about 62% from national universities, 23% from regional universities, 9% from community colleges, 5% from national liberal arts colleges, and 1% regional colleges. The selected exams were coded with the ECF until the results stabilized, which occurred after about 100 exams. Analysis showed that the Calculus 1 final exams had low levels of cognitive demand and did not address the key ideas of the course in a way that allowed students to show understanding. Of the 3735 individual exam items they coded, about 85% were at the two lowest levels of exam orientation, remembering or recall and applying procedures.

Table 1
Levels of Item Orientation (Tallman, et al., 2016)

Level	Description	Example behavior
Remember	The only requirement is the retrieval of information, not the use or understanding of it.	Stating a theorem
Recall and apply procedure	When students are asked to use a particular procedure, they can remember the procedure and use it. They need not understand why it works or under what conditions.	Use a named formula to solve a given problem.
Understand	Students must provide explanations, demonstrate their reasoning, or in other ways show that they understand.	Interpreting the meaning of a mathematical construct as applied to a real-world context.
Apply understanding	Students are not provided with information as to what formula or theorem to apply. They must decide based upon understanding.	A real-life application problem that makes clear the situation and needed result without stating anything about the techniques to use to solve the problem.
Analyze	Students must break down complex ideas and “explain how complex ideas are connected” (p. 11).	An essay in which students describe how one mathematical concept is connected to others.

Connections. This report provides information that will help institutions to evaluate the assessments they are using in their college courses and raise the cognitive level of the summative assessments used. It is our belief that teaching aligned with such assessments will encourage an active learning pedagogy in the college mathematics classroom. It is our expectation that future secondary mathematics teachers and others who take such courses will learn to think critically, to see how teaching for higher level thinking looks, and will be better equipped to help their any students they may have engage in higher level thinking.

Results

As part of an effort to collect baseline data regarding current practices, we asked faculty members in a mathematics department at a Historically Black University in the Southern United States to provide samples of the exams they used in Precalculus and Calculus. We wanted to know the level of the cognitive demand of the exam items used in these courses. Eight faculty members responded and provided 15 exams: 3 final exams, 6 Precalculus unit exams and 6 Calculus unit exams. Of the 6 Calculus exams provided, two were removed from our analysis so that any individual faculty member would not have provided more than 2 exams to the sample. An individual coder, using the first five levels of the Item Orientation framework of the ECF, coded the 6 Precalculus unit exams and the 4 Calculus unit exams. The examples provided by Tallman et al. (2016) were compared with items on the sample exams, as were verbal definitions of the item orientation levels. This analysis provided a snapshot of the level of cognitive demand of Pre-Calculus and Calculus unit exams at one HBCU.

Precalculus. A total of 102 items on 6 Precalculus exams were coded. Of those items, 3 were coded as remembering, 95 were coded as recall and apply procedure, 1 was coded as understanding, 2 were coded as apply understanding and 1 was coded as analyze. Figure 1 shows the percentages of Precalculus exam items in each level of orientation. Note that 96% of the items were at low levels of cognitive demand.

Calculus. A total of 82 items on 4 Calculus 1 exams were coded. Of those items, none were coded as remembering, 73 were coded as recall and apply procedure, 3 were coded as understanding, 6 were coded as apply understanding, and none were coded as analyzing. Figure 1 shows the percentages of Calculus exam items at each level of orientation.

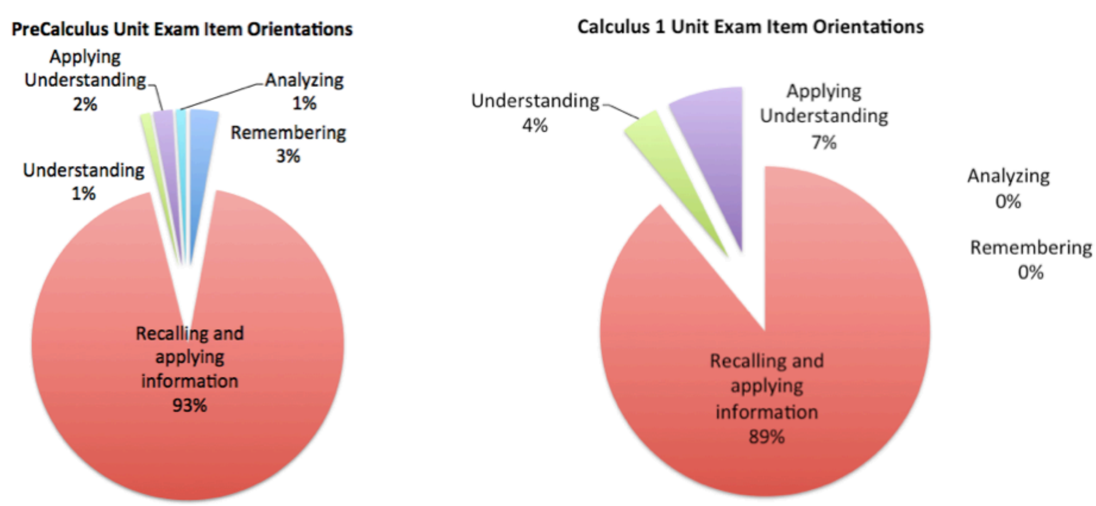

Figure 1: Levels of item orientation seen on 6 Precalculus exams (left) and 4 Calculus exams (right) provided by HBCU faculty.

Note that the percentage of higher level orientation (HLO) for the Calculus exams is better than for the Precalculus exams (11% HLO Calculus vs. 4% HLO Precalculus), but still lower than the national average for Calculus final exams (15% HLO).

Conclusion

The level of item orientation for those faculty members who submitted exams was higher for Calculus by 7% than it was for Precalculus. Precalculus students were rarely expected to think above the levels of remembering or recalling and applying procedures. Although Precalculus may be seen primarily as a precursor to Calculus and preparatory of the algebraic skills Calculus students will need, there needs to be more to the course than building algebraic proficiency. Any higher-level thinking asked of students in Precalculus will help build their ability to connect mathematical ideas, retain those ideas and engage in higher-level thinking skills in other areas of study. This is particularly important if instructors wish to produce critical thinkers that will be able to contribute to beneficial innovations in their professional fields (Tyler & Cruz, 2016; Wagner, 2011).

Talking and listening, one of the four basic elements of Active Learning, will change the passive learning from our students by having more participation in the lecture, and interaction with their classmates. These will improve the level of thinking, our next steps include increasing awareness in the mathematics department of the levels of thinking currently being expected of our students, encouraging implementations that seek to raise the level of thinking expected, and conducting research that provides evidence as to the effect of those implementations. Once change has begun in the mathematics department, it is expected that recruitment work can be more effective as we seek to increase the number of students at our institution majoring in secondary mathematics education. Tracking institutional change at the university of this study can also provide evidence for those seeking to encourage change at their institutions.

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Developing Middle School Preservice Teachers Knowledge of Number and Operations

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Abstract

We will describe how faculty members in the College of Education and the Department of Mathematics and Statistics collaborated to develop middle school pre-service teachers' mathematical knowledge for teaching relative to number and operations. We will highlight the nature of the collaboration, the activities and assessment utilized, and implications it had on preservice teachers' mathematical development.

Lawler, B. R., Ronau, R. N., & Mohr-Schroeder, M. J. (Eds.). (2016). *Proceedings of the fifth annual Mathematics Teacher Education Partnership conference*. Washington, DC: Association of Public Land-grant Universities.

Mobilizing Efforts of the MTE-P Hui

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Abstract

To build the newly established MTE-P Hui we have taken this first year to learn about the goals and activities of each of our represented groups. We have identified commonalities among our programs that will help us promote the MTE-P Hui as a platform to mediate collaboration and foster actions toward achieving our shared vision. Our initial energies are focused in two areas—increasing access to college credit-bearing mathematics courses, and ramping up recruitment in initial teacher licensure STEM programs. In this presentation we will share efforts underway for statewide restructuring and aligning community college math courses at the MATH100 and lower levels. We will also share our recruitment plans for recasting the image of mathematics teacher education to an image that includes STEM teacher education and ethnomathematics. Feedback from the attendees will be encouraged!

A Deeper Look at a Calculus I Activity

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Abstract

As a result of NSF-funded course redesign efforts to implement, promote and research active learning in introductory calculus, this paper discusses a derivative sketching activity for Calculus I. Pilot research indicates that overly-qualitative approaches to the activity often lead to certain incorrect student graphs. After revealing a deeper look at the mathematics behind the activity, the paper explores an approach to moderating the lesson in a way that leads students to a deeper understanding by activating familiar pre-requisite knowledge, without requiring mathematics beyond their zones of proximal development.

Introduction

This brief paper focuses on one course redesign approach for first-year calculus resulting from collaborations with the Mathematics FLOK (Faculty Learning for Outcomes and Knowledge) group at Fresno State. Key elements of this redesign philosophy are based on two principles inspired from mathematics education literature as well as writings in cognitive psychology and research on analogical transfer in learning (Harel, 2007):

1. The Necessity Principle: "For students to learn what we intend to teach them, they must have a need for it, where 'need' refers to intellectual need, not social or economic need." (pp. 275-276)
2. The Repeated Reasoning Principle: "Students must practice reasoning in order to internalize, organize, and retain ways of understanding and ways of thinking." (pp. 275-276)

The above principles influence the *what* and *how* topics are covered in this reform classroom. In terms of implementation, these two principles have taken form in the following recommendations for course redesign.

- Review of prerequisite material should be avoided.
- Important ideas and problem solving should commence as soon as possible so that their practice can induce recognition of patterns to problem solving.

- Active learning is essential for students to authentically internalize, apprehend and communicate mathematics.

To understand the redesign rationale from another viewpoint, suppose that an enduring an idea such as the derivative concept is viewed as a bicycle. Clearly there are many components, yet looking at them in isolation and adding more and more components to the picture does not provide a bicycle until the parts list has been completed (see Fig. 1).

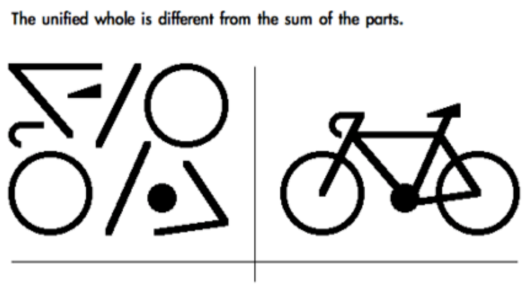

Figure 1. Learning to ride a bicycle would be near impossible from just handling the parts (I Think in Pictures, 2010).

A *Wholecept* is a cognitive structure, arrangement, or pattern of mathematical phenomena so integrated as to constitute a functional unit with properties not derivable by summation of its parts.

The Wholecept definition was originally inspired from Tall's "precept" notion which blurs the distinction between processes and concepts; but as reflection on teaching was refined, Fritz Perls' gestalt therapy writings informed the need for a dynamic element similar to the gestalt foreground/background process of conflict resolution (Grey & Tall, 1994; Perls, 1973). According to Perls, if cognitive difficulty is in the foreground, then one cannot proceed until the difficulty is resolved and made to retreat to the background so that progression can be made to deeper conflict resolution (see Fig. 2). In this respect, real conflict in student learning is not due to lack of understanding of prerequisite material, but rather to the need for a coherent picture of the "relevance" of any particular mathematical topic they are being required to learn; hence, the above recommendations.

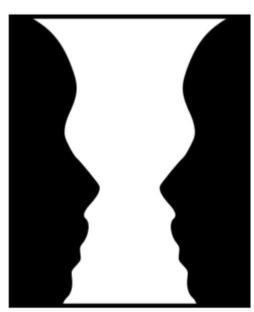

Figure 2. Rubin's (2001) famous illustration of figure-ground perception.

To restate this in terms of Harel (2007), violation of the Necessity Principle constitutes a fundamental roadblock to learning. The wholecept represents mathematical knowledge that is more "found" than constructed through a dynamic process of gradual conflict resolution and discovery. In this sense, the philosophical underpinnings of this emergent theory of mathematical learning have Platonist underpinnings, rather than being purely a constructivist view of learning. Mazur (2008) elegantly captures this viewpoint in the following quote:

When I'm working I sometimes have the sense—possibly the illusion—of gazing on the bare platonic beauty of structure or of mathematical objects, and at other times I'm a happy Kantian, marveling at the generative power of the intuitions for setting what an Aristotelian might call the formal conditions of an object. And sometimes I seem to straddle these camps (and this represents no contradiction to me). I feel that the intensity of this experience, the vertiginous imaginings, the leaps of intuition, the breathlessness that results from "seeing" but where the sights are of entities abiding in some realm of ideas, and the passion of it all, is what makes mathematics so supremely important for me. (p. 20)

Figure 3 describes the conventional approach to apprehending a wholecept, such as the *derivative wholecept*, by building up from the basics, linearly, until the derivative can eventually be defined and examples can finally begin which employ and connect the previously learned material to the main topic. A central weakness of this approach is that students often have very little time practicing problems, reasoning and communicating ideas related to the "big picture," which can contribute to poor exam performance and retention of the material. This is represented by the faintness of the final large circle in Figure 3.

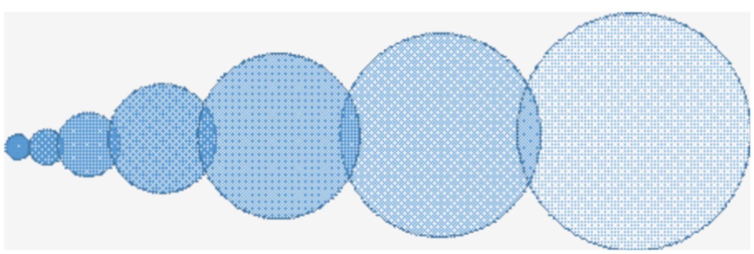

Figure 3. Unilinear concept formation—learning to ride a bike by building it one piece at a time and then trying to ride only when completed.

In stark contrast, Figure 4 depicts a very faint initial picture of the entire wholecept which, by repetition, becomes more and more clear to a point of eventual mastery. Note that the Final circle in Figure 4 is as dark as the smallest low-level circle in Figure 3, implying that the derivative wholecept has now become a functional unit applicable to a much larger picture.

To illustrate how these ideas could be applied to Calculus I, one could begin with the derivative wholecept in its entirety on the first day of class, and then continually pull in the "necessary" concepts which are needed to make it work, so to speak, so that rich problems arising from the derivative wholecept can begin and repeated as soon and as long as possible.

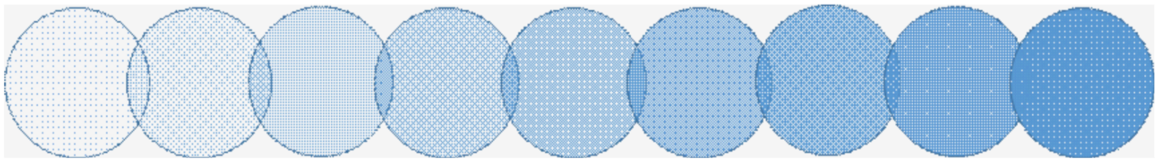

Figure 4. Wholecept resolution—taking a longer time to repetitively learn to ride a functioning bike.

Through this repetitive mantra of rich-structure problem solving, concepts such as the one-sided and two-sided limit, continuity, graphs, slopes, functions and tangent lines start to have renewed meaning. Further, this allows for the student to resolve issues of content relevancy, which may now retreat to the background, so that connections can be recognized and larger-scale problem solving patterns practiced and learned. Next, an activity in derivative sketching is discussed which is one of many weekly activities used in the infusion of active earning in calculus at Fresno State, in collaboration with the Boulder-Omaha Active Learning Alliance (2015).

Activity Description

The initial problem: *Coffee is being poured at a constant rate* v *into coffee cups of various shapes. Sketch rough graphs of the rate of change of the depth* $h'(t)$ *and of the depth* $h(t)$ *as a functions of time* t *(see Fig.5).*

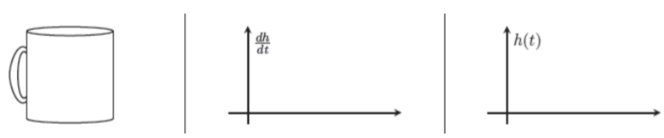

Figure 5. The cylindrical cup.

The two cup shapes discussed in this paper are the cylindrical and frustum shaped cups. In informal terms, most all students over three semesters of implementation produce qualitatively correct graphs for the straight-sided cup (see Fig. 6).

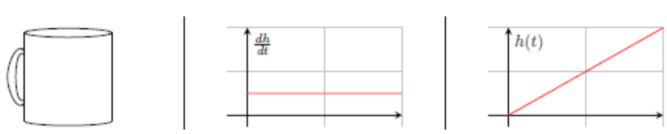

Figure 6. Cylindrical cup student solutions.

Slant-sided cup. In contrast, for the inverted frustum cup most all students produce incorrect graphs for $(t, \frac{dh}{dt})$ (see Fig. 7). In the following section, the mathematics behind these related rate graphs is discussed; however, it should be emphasized that the students participating in this activity are not expected to understand it at the depth to be discussed. An important aim of the mathematical treatment given in this paper, though, is to caution against overly qualitative approaches when a deeper understanding of the mathematics behind an activity can greatly inform pedagogy.

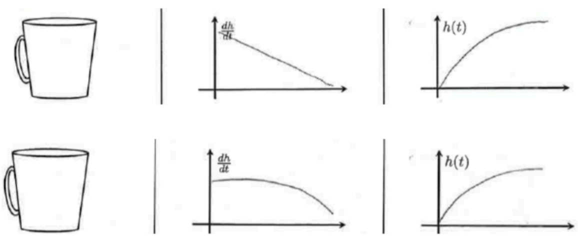

Figure 7. Typical student solutions of slant-sided cup.

A Deeper Look

Looking more closely at the cylindrical cup with base radius r_0, we can safely conclude that since the volume $V(t)$ of coffee in the cup increases at a constant rate, then so does its depth. Hence, $h'(t) \equiv\ h$ and $h(t)\ =\ ht$ (the cup being empty initially, i.e., $h(0)\ =\ 0$).

$$V(t) = \pi r_0^2 h(t)$$

Differentiating both sides relative to t

$$V'(t) = \pi r_0^2 h'(t)$$

and considering that $V'(t) = v$, we have: $h'(t) = \frac{v}{\pi r^2} \longrightarrow h(t) = \frac{v}{\pi r_0^2} t$ (given $h(0) = 0$).

As seen in Figure 6, the typically correct student graphs align well with the mathematics, since $(t, h'(t))$ produces a constant function horizontal graph, and $(t, h(t))$ consists of a linear graph through the origin with positive slope. Observe that $h'(t)$ is not the same as $V'(t)$, although this fact may elude students' attention when only a qualitative approach is applied.

For the slant-sided (inverted frustum) cup, let $r(t)$ be the radius of the surface of coffee. Then

$$r(t) = r0 + mh(t)$$

with some $m > 0$.

In this case, it appears "natural" to think of $h'(t)$ as a linear function based on the linear dependence of the radius $r(t)$ on the depth $h(t)$ which leads to the conclusion that $h'(t)$ is a *linear function* and $h(t)$ is *quadratic*. But as we shall see, this described qualitative approach fails the test by mathematics since by the conical frustum volume formula, the volume of coffee in the cup at time t is given by:

$$V(t) = \frac{1}{3}\pi[r_0^2 + r_0 r(t) + r^2(t)]h(t).$$

Instead of differentiating both sides of the above equation relative to t, which would make things more convoluted, we consider that $V'(t) \equiv v$ immediately implies $V'(t) = vt$ (with $V(0) = 0$); hence, $h(t)$ is to be found from the cubic equation:

$$m^2h^3(t) + 3mr_0h^2(t) + 3r_0^2h(t) - 3vt/\pi = 0.$$

As recalled in texts such as Boyer and Merzbach (1991), the general formula for the roots of such an equation in this case yields $h(t)$ explicitly as

$$h(t) = -\frac{1}{3m^2}\left[3mr_0 + \sqrt[3]{-27m^3r_0^3 - 81m^4vt/\pi}\right].$$

Hence

$$h(t) = a(t+b)^{1/3}\text{+c}$$

with some $a; b > 0$ and $c < 0$ such that $h(0) = ab^{1/3} + c = 0$ and

$$h'(t) = \frac{a}{3}(t+b)^{-2/3}.\ \text{Eq.[1]}$$

Letting $a = b = 1$ and $c = 1$ satisfies the initial conditions and produces qualitatively accurate graphs for $h(t)$ and $h'(t)$ (see Fig. 8)

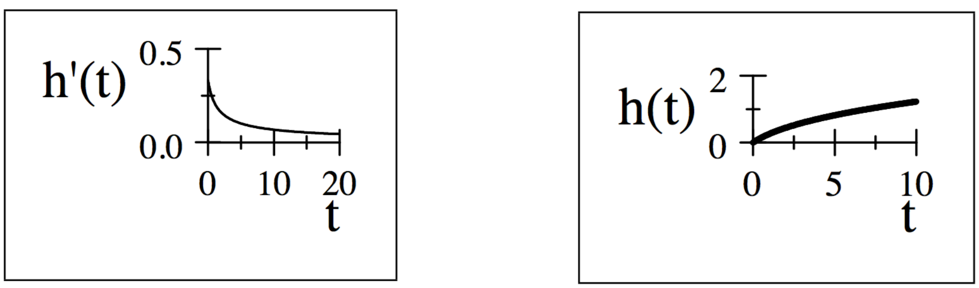

Figure 8. Frustum cup graphs.

The Exponential-Sided Cup. As a Calculus II extension of the previous analyses, the disk method performed on an exponential-sided cup highlights the mathematical depth lying behind this activity when analyzing vessels which are widening (or narrowing) (see Fig. 9).

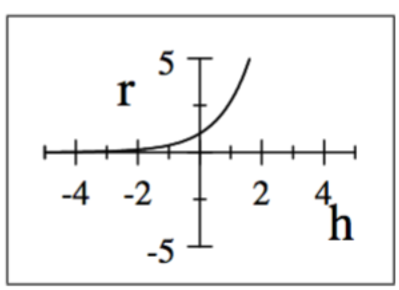

Figure 9. Flat-bottom exponential-sided cup generated by revolving $y = e^x$ around the x axis $x \to 0$ to $h > 0$.

Using the disk-method from 0 to h and employing the previous technique letting $V'(t) \equiv v$ and $V(t) = vt$,

$$V(t) = \pi \int_0^h (e^x)\,dh = \frac{\pi e^{2h}}{2} - \frac{\pi}{2} = vt.$$

whereby solving for h gives

$$h(t) = \frac{1}{2} ln\left(\frac{2vt}{\pi} + 1\right).$$

For a simpler picture, let $v = \frac{\pi}{2}$ which becomes

$$h(t) = \frac{1}{2} ln(t+1)$$

and then differentiating both sides relative to t we have

$$h'(t) = \frac{1}{2(t+1)}$$

resulting in graphs qualitatively similar to the slant-sided cup graphs (see Figs. 8 & 10).

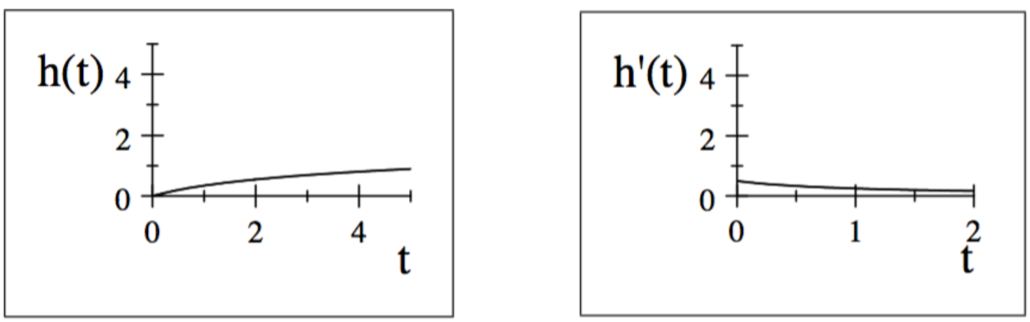

Figure 10. Exponential-sided cup graphs.

Facilitating Transfer: Known to Unknown

A first place to start when debriefing groups of students on this activity can begin with collaborative discussions about their interpretations of their graphs. For example, looking back at the slant-sided student solution graphs (see Fig. 7), after some good questioning students can arrive at the conclusion that the incorrect graphs $(t, h'(t))$ don't make sense since they imply that the rate of change of the height eventually becomes 0. A fact contradicting the constant filling of the cup, and moreover if continued, $\frac{dh}{dt}$ becomes negative implying the height function is decreasing.

On a positive note, students can also reflect on the fact that their $(t, h(t))$ graphs usually do make sense, since they start at 0 and increase, yet the rate of increase slows down as seen by the tangent lines to the graph becoming more horizontal and approaching zero, consistent with the assumption of constant filling of an increasingly widening cup of coffee. So the question remains, how can students arrive at correct $(t, h'(t))$ graphs given the mathematics they know? *Analogical problem construction (APC)* refers to "letting students construct their own analogous problems,… [which] allows the problem solver to use his or her own knowledge and experiences to create the analogical problem elements" (Bernardo, 2001, p. 138). In a mathematics study on APC, Bernardo (2001) found that,

One can use a rather structured task, and still allow students to explore and engage the information in math problems enough to lead them to deeper levels of understanding of the problems which increase analogical transfer performance. (pp. 147-148)

This paper concludes with some structured examples for how APC can be induced in the context of this activity.

Conclusion

Promoting analogical problem construction in the context of this calculus activity can begin by asking students to collaboratively produce familiar functions that resemble their $(t, h(t))$ graphs. After discussion and concensus, they can be asked to find the derivative graphs of these familiar functions and compare them to those made in the cup activity. As an example, the following two functions are familiar to most students and have graphs that match the initial conditions and have the same qualitative shapes as their correctly produced $(t, h(t))$ graphs:

- $h(t) = \sqrt{t}$
- $h(t) = ln(t + 1)$

At this point in the course material, calculus students can easily take these derivatives and sketch their graphs (see Figs. 11 & 12), and then compare them to the ones they produced. Important topics such as concavity can be discussed as well as subtleties, such as the difference between Figures 8 and 11, where in Figure 11 the $(t, h'(t))$ graph appears to be infinite at $t = 0$; illustrating the degenerate case when the frustum is a cone (see Eq.[1], and consider when $b = 0$).

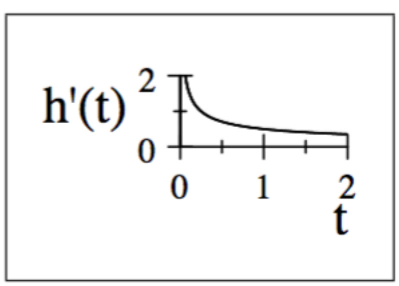

Figure 11. $(t, \frac{1}{2\sqrt{t}})$ graph.

As this activity is done at the end of the semester, when anti-differentiation has been covered, the previous line of questioning involving graphing the derivative of familiar functions of $(t, h(t))$ can be reversed to the case of finding familiar functions to their $(t, h'(t))$ graphs, and exploring problematical issues associated with graphs of their anti-derivatives.

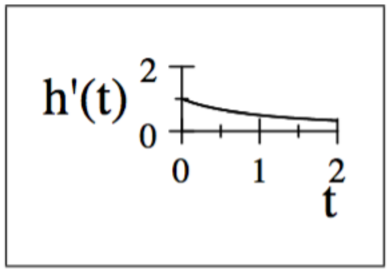

Figure 12. $(t, \frac{1}{t+1})$ graph.

For example, the following two functions have the same qualitative shapes as their typically *incorrect* $(t, h'(t))$ graphs (see Fig. 7):

- $h'(t) = -2t + 3$
- $h'(t) = -t^2 + 2$

Recalling the initial condition that $h(0) = 0$ then for both antiderivatives $C = 0$; hence,

$$\int -2t + 3dt = -t^2 + 3t + C = -t^2 + 3t$$

$$\int -t^2 + 2dt = \frac{t^3}{3} + 2t + C = \frac{t^3}{3} + 2t$$

The anti-derivitive computations produce the above non-sensical graphs, which may promote rich discussions as they are problematical for a variety of reasons, one being they imply the height increases then decreases, again contradicting the assumption of constant filling of the coffee cups, (see Figs. 13, 14).

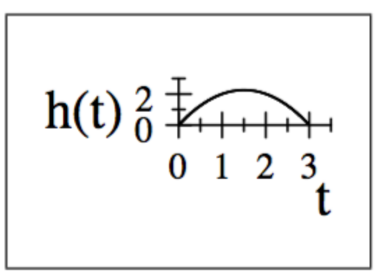

Figure 13. Anti-derivative graph for $h'(t) = -2t + 3$.

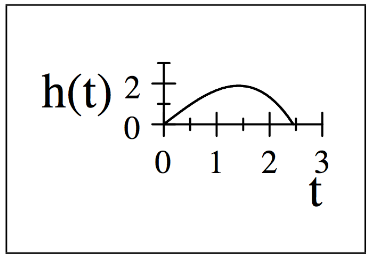

Figure 14. Anti-derivative graph for $h(t) = -t^2 + 2$.

In summary, although active learning can and should involve fun, interactive and concrete ways to explore mathematical concepts, a deeper understanding and exploration of the underlying mathematics by the instructor should not be avoided, as it can hold the keys to unlocking latent student knowledge already lying dormant within.

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Teaching College Geometry using Geometry MODULE(S^2)

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Abstract

The Geometry modules developed by the MODULE(S^2) Research Action Cluster was adopted and implemented to our College Geometry course, Math 329 at California State University, Monterey Bay during Fall 2015. Our College Geometry course is designed for Mathematics majors in the subject matter preparation (Teaching) concentration. This was the first time we adopted pedagogy for our Geometry course that focused on preparing high-quality mathematics teachers to teach the new generation of students in California schools under the Common Core standards. Earlier our course was taught as a content-based mathematics course in a traditional way. There were three modules in this new models, each followed an inquiry based learning approach that required a good amount of reading, writing and self-exploration by students inside and outside of classroom. The course also required group work on class activities and outside class assignments along with peer reviews of each other's work. This was a very new approach for our Geometry students. In this presentation, we will discuss how we adopted and implemented the modules for our students and how students learned Geometry in a new way that prepared them to be effective math teachers. We will share how our students reacted to the modules, our challenges teaching the course and discuss if this approach made any difference in preparing future quality mathematics teachers.

Geometry Teaching Knowledge: A Comparison Between Pre-Service and High School Geometry Teachers

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Abstract

This study compares Geometry Teaching Knowledge between pre-service and high school geometry teachers. Data was collected via an online MKT-G assessment developed by Herbst and Kosko (2014), a post-assessment survey, and interviews of three pre-service teachers and four high school teachers. Furthermore, this study also investigates where this knowledge is developed. Pre-service teachers did not perform as well as the high school geometry teachers in all of the domains: Geometry Content Knowledge, Specialized Geometry Knowledge, Knowledge of Geometry and Students, and Knowledge of Geometry and Teaching. When comparisons were made regarding experiences in pre-service teacher education courses, pre-service geometry courses, high school teacher professional development opportunities, current geometry classrooms, and ideal classrooms of both pre-service and current high school teachers, there were statistically significant differences. This study provides insight into the domains of Geometry Teaching Knowledge that could be used in making decisions regarding pre- service teacher education programs and high school geometry teacher professional development.

Repurposing the MCOP² Observation Protocol to Survey Students' Views of an Active Learning Course Redesign

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The goal of the Active Learning in Mathematics Research Action Cluster (RAC) is to study the process by which lower division university mathematics courses can be redesigned to engage students in active learning practices such as forming hypotheses, creating mathematical models and discussing their ideas with others. As with many other Mathematics Teacher Education Partnership (MTE-P) initiatives, implementing this vision involves successive Plan-Do-Study-Act (PDSA) cycles (Bryk, Gomez, Grunow, & LeMahieu, 2015). This paper reports on one such cycle that focused on developing a survey instrument to measure students' perceptions of active learning opportunities by transforming the Mathematics Class Observation Practices Protocol (MCOP²; Gleason, Livers, & Zelkowski, 2015) from a teacher observation tool to a student survey.

The problem we were addressing was that while we had a *Plan* and were ready to *Do* the work, we didn't have a way to *Study* our implementation. Our *Plan* was to develop weekly modeling projects that would highlight real-world applications of the seemingly abstract functions studied in Pre-Calculus. In order to *Do* this, we had to work with our administration to augment the large lecture sections with small break out sections capped at 30 students, and to devise weekly labs that would include opportunities for active learning. Our *Study* of this work involved repurposing the MCOP² observation protocol (Gleason, & Cofer, 2013) into a student survey so we could get a picture of what the students thought about the labs and measure the degree to which these labs actually engaged students in active learning practices. The conclusion to this paper describes how we plan to *Act* to refine our redesign efforts in future semesters.

Background

One of the more far-reaching and comprehensive studies documenting the effectiveness of active learning in university science, technology, engineering and mathematics (STEM) courses was conducted by Freeman et al. (2014). In their meta-study of 225 research papers describing active learning in various settings, the authors conclude that student performance

Lawler, B. R., Ronau, R. N., & Mohr-Schroeder, M. J. (Eds.). (2016). *Proceedings of the fifth annual Mathematics Teacher Education Partnership conference*. Washington, DC: Association of Public Land-grant Universities.

on final exams and other conceptual tests increased by almost .5 standard deviations in classes with active learning versus traditional lecturing. In addition, other studies have found that active learning have demonstrated decreased failure rates (Henry, 2010), improved student engagement (Freeman et al., 2014), persistence in taking subsequent courses in the Precalculus to Calculus II sequence (Laursen, 2013) and improved attitudes toward mathematics for female and under-represented populations (Laursen et al., 2014). While all of these studies used different measures of success (final exam grades, persistence, and student attitudes, respectively), none of the studies actually measured the degree to which the students perceived they were engaging in active learning. Our goal was to develop a measure of the students' perception of active learning and try to identify the "value added" between the lecture and active learning labs from the students' point of view.

Description

The MCOP^2 tool was developed to help researchers measure the degree to which classroom practices align with various teaching reform documents such as the Standards for Mathematical Practice (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). We chose this tool because it focuses on many aspects of active learning and because it has been proven to be both reliable and valid (Gleason, Livers & Zelkowski, 2017). However, its use also poses some challenges. First, it is resource-intensive due to the need to train and pay observers; in our case the observers would have to observe at least five lectures and 32 break out sections multiple times across a semester. Second, it only captures snapshots of the lessons observed, and is limited to the observer's perspective. In order to capture the students' perspectives over the course of the semester, we modified the tool to be used as a student survey. Although one could argue that trained observers might be more astute at seeing opportunities for participation than students, our hypothesis was that if students do not see an opportunity for engagement (even if one may exist in the eyes of the observer), then they are not developing the metacognitive awareness needed to engage in these practices as they prepare for more challenging courses.

Our method involved three stages: (1) modifying the protocol and administering it online to all students enrolled in the course, (2) analyzing the modified protocol by conducting a confirmatory factor analysis, and (3) analyzing students' survey responses, including to the open-ended responses to questions regarding their enjoyment of various labs. During the modification process, we attempted to limit the amount of time students needed to spend answering items by rewording the items to accommodate both the lecture and lab settings. We cut the 16 MCOP^2 items in half, to ask the eight questions most relevant to student experiences, but then asked each question twice: once about students' experiences in lectures, and once for their experiences in the labs. Thus, for example, question 1 was stated as follows, "During my lecture class, students engaged in exploration/investigation/problem solving about how much of the time? [regularly, sometimes, seldom, never]". Question 2 read, "During my lab class, students engaged in exploration/investigation/problem solving about how much of the time? [regularly, sometimes, seldom, never]". Thus, all odd-numbered questions refer to lecture while even-numbered questions refer to labs. The eight pairs of items asked students about engagement in exploration/investigation/problem solving, use of tools, time to work on questions, discussion of solution strategies, perseverance, conceptual links within the mathematics, mathematical modeling, and precise mathematical language.

During the second phase of this work, we asked all students to take the survey online. Of the 706 students enrolled in 6 sections of the course, we received 504 completed surveys—over a 70% response rate. This return rate is significant enough to claim that the results are representative of most students. We examined the students' answers to the open-ended questions by determining the most common comments and putting them together in categories.

The analysis of the student responses involved conducting a confirmatory factor analysis to gauge the degree to which our students' answers aligned with the MCOP^2 factors that Gleason, Livers and Zelkowski (2015) found when they used an exploratory factor analysis to establish the reliability of the MCOP^2. Their initial factor analysis revealed two subscales: Teacher Facilitation and the Student Engagement. The teacher facilitation subscale (Cronbach alpha of 0.850) measures the degree to which the teacher plans lessons, promotes problem solving, and facilitates classroom discourse. The student engagement subscale (Cronbach alpha of 0.897) measures the degree to which students engage in the learning process.

Results

The results of the confirmatory factor analysis revealed that the MCOP^2 student survey did have the same factor structure as the original observation tool (Teacher Facilitation and Student Engagement). The five items chosen from the Teacher Facilitation scale and three items from the Student Engagement scale loaded onto separate scales for the MCOP^2 survey. However, within the two expected factors, two additional factors also emerged: LAB and LECTURE. Thus, the 16 total items could be split into four factors: Teacher Facilitation-Lab (5), Teacher-Facilitation-Lecture (5), Student Engagement-Lab (3), Student Engagement-Lecture (3). All four factors had good model fit according to model fit indices (Chi-square, CFI, TLI, RMSEA, and SRMR). In addition, all factor loadings and R^2 coefficients were statistically significant.

The modal responses for the lecture and lab are shown in Figure 1. As can be seen, the students rated the labs higher in every category than lecture in terms of offering opportunities for active learning. The two areas that showed the greatest "value added" were exploring solution pathways (Cohen's *d* effect size of .51) and discussion of solution strategies (Cohen's *d* effect size of .43).

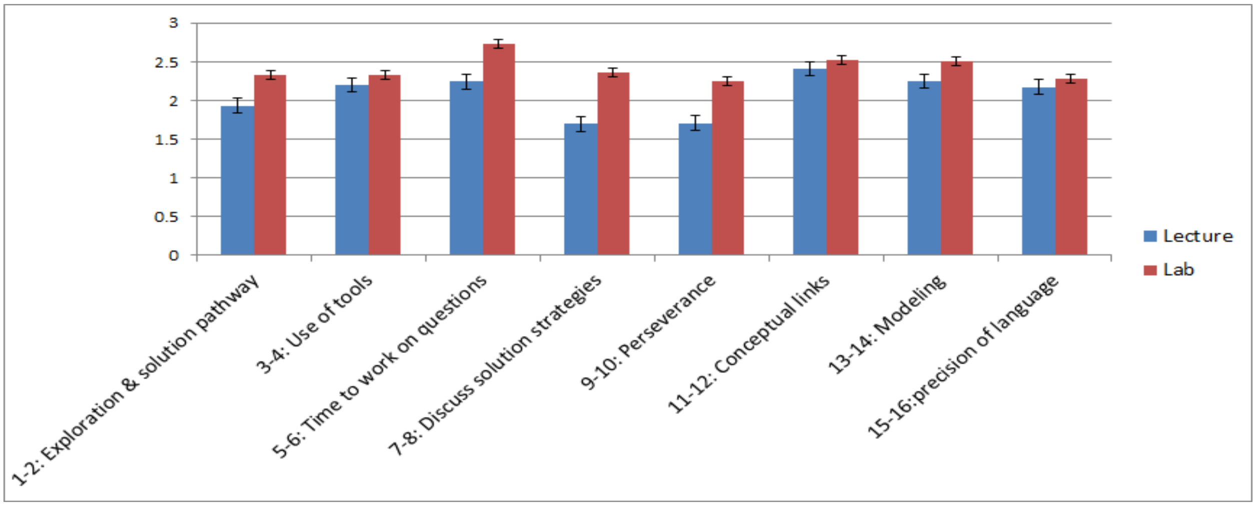

Figure 1. Modal responses on modified MCOP^2 from student reports of active learning in lecture and lab classes.

The open-ended results indicated that over 70% of students were either happy or very happy with the labs. In particular, many of them noted their relevance to real life. For example, one wrote “I enjoy the active labs where you have to get up and collect data by interacting with others. It actually makes math semi fun.”

Conclusion

This study revealed two key findings that will inform our work going forward. First, the MCOP^2 student survey does align with the factors used to validate the MCOP^2 protocol, and hence appears to be reliable; since the larger RAC had already determined the MCOP^2 observation instrument to be a valid measure aligned project goals, a subset of these items posed as a survey would retain that validity. Second, the survey is useful for identifying what students believe are specific value-added aspects of active learning that the labs offer to augment lecture.

This work impacts our institution because we are in the process of redesigning the entire Precalculus to Calculus 2 sequence. Hence, we will be able to use the revised survey in all three courses to measure gains in active learning. The work contributes to MTE-P because it offers a second use for the MCOP^2 tool for members wishing to report students’ perspectives and perhaps compare results with those of trained observers.

Our next steps for concluding this PDSA cycle are to *ACT* as follows: (1) revise the wording of the survey to make it more “student friendly,” (2) compare student results with outside observers, (3) shift some of the choices from estimations of percent of student engagement to measures of personal engagement, and (4) compare survey students in lecture-only classes versus those who have both lecture and lab classes. Furthermore, other universities participating in the Active Learning Mathematics Research Action Cluster may begin to use the MCOP^2 survey to better understand their students' experiences in reformed mathematics classrooms.

For More Information

- For more information and/or to obtain a copy of the survey, please contact Janet Bowers at San Diego State University – JBowers@mail.sdsu.edu
- For more information about the confirmatory analysis methodology, please contact Wendy Smith at University of Nebraska-Lincoln – wsmith5@unl.edu
- The original MCOP^2 survey and documentation can be found online: jgleason.people.ua.edu/mcop2.html

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Active Learning Mathematics at the University of Nebraska-Lincoln

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One of the top two goals of the Math Teacher Education Partnership (MTE-P) is to increase the quantity of secondary mathematics teachers prepared at the partner institutions by 40%. Such an increase necessarily involves more undergraduates interested in mathematics. Typically, before undergraduates become mathematics majors, they take one or more freshman-level mathematics courses (precalculus to calculus 2). However, in 1987 mathematicians reported that "as many as 40% of undergraduates were failing introductory calculus, and even those who passed did not appreciate the subject's relevance" (Wilson, 1997, p. A12). More recently, the Characteristics of Successful Programs in College Calculus (Bressoud, Carlson, Mesa, & Rasmussen, 2013) showed failure rates (grades of D, F or Withdraw) ranged from an average of 25% at Ph.D.-granting universities to an average of 37% at regional comprehensive universities. Thus, improving students' experiences in freshman-level mathematics courses is a logical prerequisite to increasing the number of undergraduates who seek to become mathematics teachers.

In recent years, research overwhelmingly has shown that active learning strategies are effective at increasing student success in undergraduate science and mathematics courses (e.g., Bressoud & Rasmussen, 2015; Freeman et al., 2013; Laursen et al., 2011; 2014), particularly for underrepresented groups of students. Thus, the MTE-P chose to focus one of its five initial Research Action Clusters around Active Learning Mathematics (ALM RAC). The Department of Mathematics at the University of Nebraska-Lincoln (UNL) was one of the founding members of this ALM RAC, having already begun efforts to improve precalculus courses. The mathematics department also embraced the MTE-P *Networked Improvement Community* (NIC; Bryk et al., 2015; Martin & Gobstein, 2015) model. Working as part of the ALM RAC has allowed UNL to accelerate course improvements by building on the learning of other ALM RAC institutions. Further, the positive results of implementing active learning in precalculus has institutionalized these practices at UNL.

UNL utilizes the ALM RAC definition of active learning: *We define ALM as teaching methods and classroom norms that promote: (1) students' deep engagement in mathematical reasoning, (2) peer-to-peer interaction, and (3) instructor inquiry into student thinking. In*

Lawler, B. R., Ronau, R. N., & Mohr-Schroeder, M. J. (Eds.). (2016). *Proceedings of the fifth annual Mathematics Teacher Education Partnership conference*. Washington, DC: Association of Public Land-grant Universities.

support, the curriculum should focus on key mathematical ideas, including the use of tasks that promote sense making and procedural fluency. Student activity should favor opportunities for them to propose questions, communicate reasoning, and share solutions in process. Instructor activity should showcase practices that promote student engagement and build on student thinking to advance the mathematical agenda. This classroom description is represented in Figure 1.

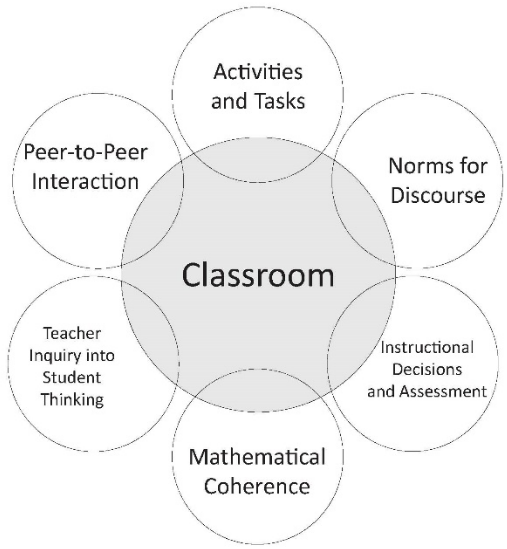


Figure 1. Classroom-level ALM features.

Adopting an active learning approach to instruction is only one component of a larger institutional transformation to improve student success in mathematics. Besides faculty leadership, active campus and departmental leadership are also critical to successful institutionalization of ALM. Departments committed to institutional transformation attend to student data, particularly placement data, student trajectories through courses, and student success. In addition to effective leadership and intellectual resources, physical resources such as classroom furniture and class minutes per week also can contribute to or hinder institutional transformation—represented in Figure 2. UNL has committed to institutional change at the departmental and classroom levels. The overall purpose of this brief report is to summarize the UNL efforts to transform freshman-level mathematics courses and raise student success.

Background

The research team at UNL collects extensive data each semester about the students in the precalculus and calculus courses. This brief report focuses on documenting the institutional changes at Nebraska, drawing mainly on the quantitative data collected about students and courses. UNL joined the Big Ten in 2011, and started to focus on raising the six-year graduation rates and freshman retention rates. At UNL, over two-thirds of freshmen take a mathematics course in their first semester; no other department even garners half of first-time freshmen enrollment. Thus, freshmen retention correlates very highly with passing precalculus and calculus mathematics courses.

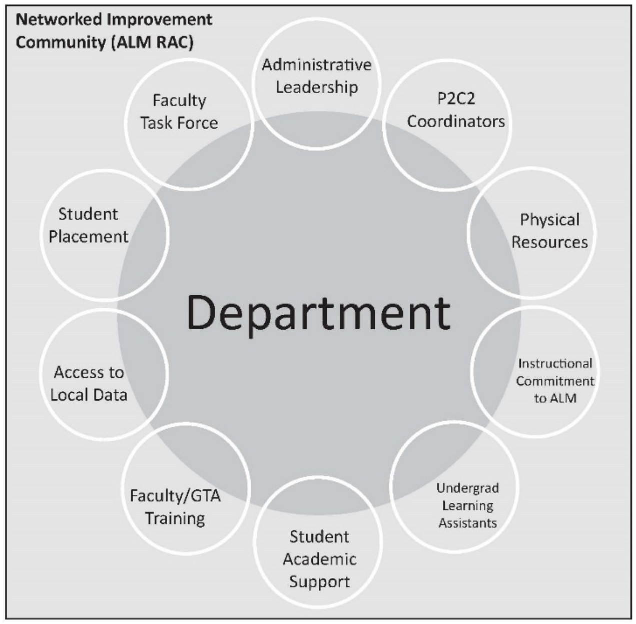


Figure 2. Department-level ALM features.

At UNL, fall enrollment in mathematics courses tends to be approximately double that of spring enrollment. In Fall 2015, approximately 1,500 students took one of four types of precalculus courses, and approximately 2,000 students took calculus 1 or 2. Precalculus courses at UNL include: Intermediate Algebra (3 credit hours but does not count as mathematics credits), College Algebra (3 credit hours), Trigonometry (2 credit hours), and College Algebra &Trigonometry (5 credit hours; the union of the previous two courses listed).

Table 1

Relevant parameters of Active Learning Mathematics context at UNL

UNL – By the Numbers (Fall 2015)	
All Students	25,260
Undergrads	20,182
First Time Freshmen Average ACT Score	25.2
University-wide Freshman/Sophomore Retention	82.5%
6-year graduation	67.0%
Math GTAs	77
Math Tenure-track Faculty	29

Methods to Improve Freshman Success in Mathematics

With substantial variation across sections, historical success rates[1] in College Algebra and College Algebra & Trigonometry (2007-2011) hovered in the low-60% range. The first efforts to improve these courses involved an emporium model, in which students worked at their own pace through materials in a computer lab, with graduate teaching assistants (GTAs) available to answer questions. That model was quickly abandoned in 2012, at which time the focus shifted to active learning approaches.

UNL invested considerable resources into implementing active learning, addressing all of the components in Figure 2. Success rates now are steady at around 80%. Key efforts included First-Year Mathematics Task Force, hiring a Precalculus Coordinator, strong administrative leadership and physical resources, the use of Learning Assistants, a course readiness activity, and an effort to improve students' online homework experience. Each is discussed next.

The First-Year Mathematics Task Force was a faculty committee dedicated to improving freshman-level mathematics courses; a key role was to evaluate the quality and difficulty of the exams, to provide assurance that improved success rates were not due to lowering of mathematical standards. The task force also marshalled and made sense of local data, to help inform the ongoing efforts.

UNL hired a full time assistant professor of practice to serve as coordinator for the four precalculus courses and to oversee the training and ongoing mentoring of GTAs. Close coordination of the courses includes not just a syllabus and common exams, but also detailed lesson plans, to reinforce a model of class time dominated by students doing mathematics in groups, and engaging in small-group and whole-class discussions to make sense of the mathematics. The first-year GTAs are responsible for teaching their own course (in sections of 40 students), and they are required to take a year-long teaching seminar. To balance this demand, the GTAs' first-year teaching assignment is one course each semester; in later years, GTAs teach two courses in the fall and one in the spring.

Due to strong administrative leadership, multiple classrooms on campus were renovated to include moveable tables and chairs, and whiteboards all around the room, and then dedicated to house math courses. Additionally, understanding that active learning takes more time than lecture, while the credit hours remained constant, the minutes per week in College Algebra were increased from 150 to 225, and the minutes per week in College Algebra & Trigonometry were increased from 250 to 300.

A final effort was the implementation of Learning Assistants into the precalculus and calculus mathematics courses. The department hires undergraduate learning assistants, initially

[1] Success here means the student earned a C or better in the course (or Pass if taken pass/no pass).

grant-funded, to help in the precalculus courses and to serve as an additional instructor to facilitate group discussions.

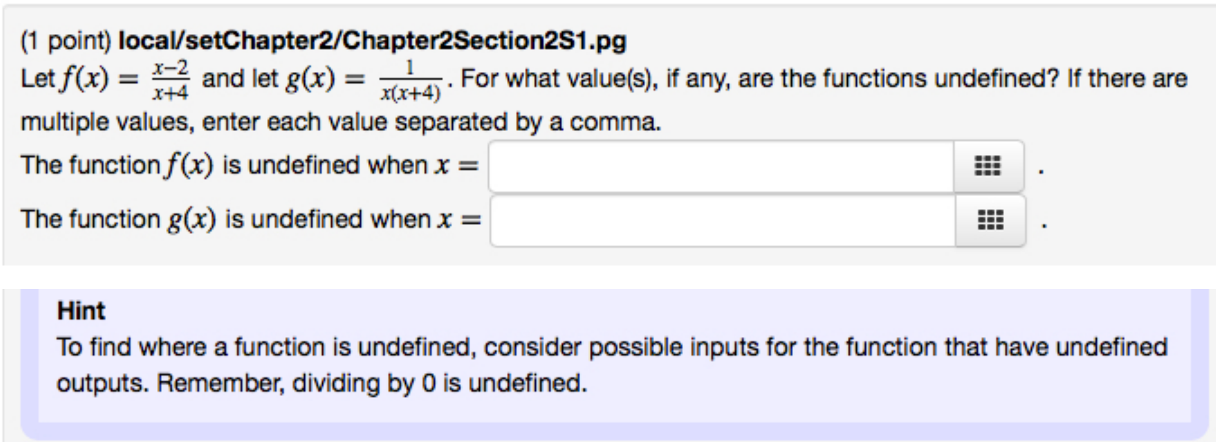
In addition to the above activities, the Department of Mathematics also decided to institute a test on the first day of class, covering prerequisite material, and which can serve as a check on course placement. The department quickly learned to call this a “course readiness activity” rather than “prerequisite mastery exam”; students who did not pass on the first day were allowed to retake the test once per day for two weeks in the college testing center. Students could get review packets and work on these in the Math Resource Center (tutoring room staffed by GTAs and undergrad math majors) with their instructor or learning assistant.

This course readiness activity sorted students into three groups: those who passed on the first day (know the material); those who eventually passed (invested time to relearn material); those who never passed (no obvious time investment). Most of the “never passed” group never attempted to take the test in the testing center at all. This course readiness activity has proved to be incredibly predictive. Those in the first two groups (pass/eventually pass) average 80% on the course exams (three exams + final), with 75% of students in those groups earning grades of 75% or higher. Students in the “never passed” group averaged under 60% on course exams, with nearly 75% of these students earning grades below a C. Among the students who do not pass the course readiness activity on Day One, the chances to retake the test seem to help distinguish students’ “college readiness” skills of being able to engage in positive habits such as studying and seeking help.

Once the mathematics department realized the predictive ability of this course readiness activity (Fall 2014), the department sought to implement interventions with the “never passed” group in Fall 2015. The interventions targeted math skills, and were successful in raising student exam averages higher than the previous years’ “never passed” group, but not to the level of those students who did pass this initial test. Future interventions may need to find a way to incorporate broader “college readiness” skills.

Finally, an internal grant allowed two faculty members to improve the online homework experience for students. UNL uses WeBWorK, an open-source platform, to deliver online homework assignments to students, as a way to provide students opportunities to practice what is learned in class. WeBWorK was adopted in 2013, following the previous use of MyMathLab. Students get multiple attempts per item; the online system allows students to know immediately if their answers are correct. Yet, knowing an answer is incorrect almost never helps a student determine how to correctly solve a problem.

Students were initially frustrated that WeBWorK lacked the “hint” feature of MyMathLab, in which a student could see the same problem (with different numbers) worked out in a step-by-step fashion. However, this type of hint emphasizes procedure memorization, and the department wanted to emphasize conceptual understanding. Thus, through this internal grant, experienced GTAs and several high school teachers were hired to create more conceptual hints to target common errors or misconceptions. These new hints were designed to be the question an instructor would ask, or a reminder an instructor would give to students who were stuck on a problem, such as the one shown in Figure 3.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Let $f(x) = \frac{x-2}{x+4}$ and let $g(x) = \frac{1}{x(x+4)}$. For what value(s), if any, are the functions undefined? If there are multiple values, enter each value separated by a comma.

The function $f(x)$ is undefined when $x =$ ____ .

The function $g(x)$ is undefined when $x =$ ____ .

Hint

To find where a function is undefined, consider possible inputs for the function that have undefined outputs. Remember, dividing by 0 is undefined.

Figure 3. Sample improved hint offered in the WeBWork environment.

WeBWorK allows a department to keep track of problem-level data, so the Department of Mathematics could track the questions with and without hints. Students earned more points, on average, on homework questions that included these new hints. In response to an end-of-semester survey, 84% of students reported using the hints at least once, and 87% of those students found the hints to be at least occasionally helpful, demonstrated in Figure 4. In crafting hints, the goal was to address the most common misconceptions, knowing that the hints would not be able to comprehensively address every possible student error.

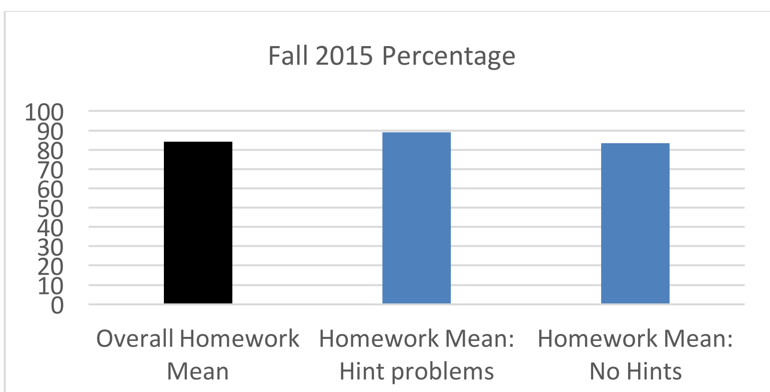

Figure 4. Results of student survey showing the difference in homework scores on problems with and without hints.

Conclusion

The research team at UNL continues to be involved in the ALM RAC. With active learning well-established (successfully) in precalculus courses, the focus in 2016 is on extending active learning strategies into calculus 1 and calculus 2 courses. In those courses, taught in large (150) lecture with small (25-30) recitations, the lectures are now infused with numerous clicker questions, which the instructor can follow up by having students discuss with students nearby. The recitations have shifted from 100 to 150 minutes per week, and instead of serving as times when students watch a GTA solve homework problems, now these recitations serve as time for students to work collaboratively on new problems.

The WeBWorK hints are expanding to other courses (initial funding focused on College Algebra). A future goal is to create some short video hints, in which an instructor gives a very brief (less than 3 minutes) lecture about the topic, covering more of the common misconceptions.

Finally, the UNL research team is part of a new grant from the National Science Foundation, titled *SEMINAL: Student Engagement in Mathematics through an Institutional Network for Active Learning.* SEMINAL seeks to study transformed departments like those at UNL, University of Colorado-Boulder, and San Diego State University, as well as departments at earlier stages of transformation, both inside and outside the ALM RAC. By focusing on the Networked Improvement Community model, what SEMINAL learns about departmental transformation can be rapidly disseminated to the rest of the ALM RAC, as well as to the MTE-P more broadly, to support the propagation of improved student success.

For More Information

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- Contact – Wendy Smith, University of Nebraska-Lincoln, wsmith5@unl.edu

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Using the MCOP^2 as a Grade Bearing Assessment of Clinical Field Observations

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The development and validation of observation protocols for lessons implemented in mathematics classrooms is scarce. That is to say, protocols for mentor teachers or university supervisors to use when observing and scoring preservice mathematics teachers are virtually absent in the field of mathematics teacher preparation. Departmental or program checklists, aligned to discipline-agnostic state teaching standards, are more commonly used for preservice teacher observations (Brown & Crippen, 2016; Caughlan & Jiang, 2014; Morrell, Flick, & Wainwright, 2004). Because many secondary mathematics teacher preparation programs (SEMA-TPP) are housed in departments of education, secondary mathematics educators located in a Mathematics department may have little flexibility with regards to the documentation of generalist practices, dispositions, and standards common across disciplines. Further, the accreditation *unit* is often the Secondary Teacher Preparation Program rather than the more discipline-specific SEMA-TPPs. To add to this complication, most SEMA-TPP's are small, providing limited opportunity to collect large-scale data in a reasonable amount of time to do rigorous quantitative analyses.

Within a similar context, the University of Alabama (UA) mathematics education faculty developed a research-based observation protocol for K-16 mathematics classrooms usable for cooperating mathematics mentor teachers, supervisors, and faculty. The Mathematics Classroom Observation Protocol for Practices (MCOP^2) was developed during 2012-15 to evaluate a large, grant-funded professional development project. The research on the development of MCOP^2, validation, reliability, and factor analyses resulted in strong findings. Without training, good interrater reliability on the two factors was determined (IRR=0.669 on student engagement [SE], IRR=0.616 on teacher facilitation [TF]). On the two factors, SE had an $\alpha=0.897$ and the TF had an $\alpha=0.850$. Finally, the two national surveys of experts in the field produced a strong external validation of the MCOP^2 (Gleason, Livers, & Zelkowski, 2017).

This brief research paper presents the results from a two-year study in the UA SEMA-TPP to align grading practices of the MCOP^2 with previous un-validated generalist observation forms. The generalist observation forms have historically been used at UA to address state teacher preparation standards, as well as to determine letter grades assigned to lessons conducted by grades 6-12 preservice mathematics teachers. We set out to determine: (1) What grading scale would be appropriate on the MCOP^2 and correlate well to the grades received on the generalist observation form? (2) How do preservice teachers perceive the MCOP^2 as their grade-determining observation protocol, as opposed to the generalist observation form? (3) Does preparing preservice teachers to consider the MCOP^2 in their planning of formal observation lessons improve the quality of the lessons than prior to the MCOP^2 implementation? (4) What are the impacts for both students and program to use the generalist form as a non-grade-bearing, end-of-semester, summative form, and the MCOP^2 as the exclusive grade-determining observation protocol for both methods students and student teachers?

Institutional Transformation of SEMA-TPP to the College

In 2008, the first author arrived at UA to lead the SEMA-TPP and quickly joined forces with the second author, a mathematician responsible for the curriculum of the secondary mathematics major track. A partnership was created and the secondary mathematics education major track was aligned to the recommendations of *The Mathematical Education of Teachers* (Conference Board of the Mathematical Sciences [CBMS], 2001), and later *The Mathematical Education of Teachers II* (CBMS, 2012) ensued. Changes included developing a second capstone course, revising the first capstone course, inserting analysis and differential equations as requirements, and adjusting the programming ancillary course. On the education side, three methods courses were aligned sequentially alongside the capstone math courses, and structured to create a two-year cohort model to develop habits of mind and mathematical practices that relate to teaching mathematics with quality tasks in a manner that maintains high level cognitive demand (Stein, Smith, Henningsen, & Silver, 2009).

A few years later, the development and use of the MCOP^2 spurred the entire college to begin transforming other secondary education programs, with Social Studies and English programs utilizing structures similar to mathematics. These initial transformations led to development of a third capstone course that has since been piloted twice and will become permanent in the Fall of 2017. The transformation of the SEMA-TPP since 2008, and more recently with the MCOP^2, has moved the preparation program to a point that the *quality* of our graduates and their ability to model best practices *regularly* has out-performed an old philosophy in which the *quantity* of graduates was of greater concern. Initially, resistance came administratively, but the program rigor, voluntary NCTM SPA accreditation review, and research-based design convinced other disciplines to transform. Both program quality and quantity have increased without reduction of rigor.

Theoretical Framework for the MCOP^2

The MCOP^2 became an important mechanism to the SEMA-TPP to communicate expectations for mathematics instruction, to provide feedback to secondary mathematics students as they designed and implemented lessons, and to evaluate the results of the program. The MCOP2 was designed to reflect the important qualities of mathematics instruction as advised by the profession. For example, conceptual understanding focuses on students drawing, inferring, and ultimately making connections between mathematical operations, representations, structure, reasoning, and modeling through engagement with content and through discourse (Brownell, 1935; Hiebert & Carpenter, 1992; Hiebert & Grouws, 2007; National Research Council, 2003 Resnick & Ford, 1981; Skemp, 1971, 1976). With that said, a preservice teacher's lesson would not fit well within a goal for conceptual understanding if the lesson focused solely procedural fluency and efficiency through instructional practices such as drill worksheets emphasizing procedures to be learned by rote. This practice may be beneficial at times within the larger context of mathematics instruction, though should be neither the primary method of instruction; it fails to engage students in doing and understanding mathematics beyond procedural fluency. Furthermore, "there is no reason to believe, based on empirical findings or theoretical arguments, that a single method of teaching is the most effective for achieving all types of learning goals" (Hiebert & Grouws; 2007, p. 374).

From the beginning, Cohen, Raudenbush, & Ball's (2003) theoretical model of instruction as interaction between teachers, students, and mathematical content guided the development of the MCOP^2 framework of teaching for conceptual understanding through various forms of instructional practices. The team began with examining the commonly used Reformed Teaching Observation Protocol (Sawada et al., 2010) as well as the Standards for Mathematical Practice (SMPs) from the Common Core State Standards, which have been shown to align well with the NCTM process standards (Koestler, Felton, Bieda, & Otten, 2013). We then considered the UA SEMA-TPP program standards, well-aligned to the NCTM Specialized Professional Association (SPA) standards (NCTM, 2012), and assigned connections between these standards and the Cohen et al. (2003) model. As seen in Figure 1, the Instruction as Interaction model developed at UA presents three nodes, or factors, which could be denoted as teacher responsibilities, mathematical content of the lesson, and student engagement.

At the completion of the aforementioned factor analysis (Gleason et al., 2017), a two-factor structure of the MCOP^2 was found, as opposed to the initial design of three factors seen in the Instruction as Interaction model. The final instrument more closely aligns with Rogoff, Matusov, and White (1996), a framework characterized by a community of learners in which authority and responsibility are shared among students and teachers. This is evident in our model (Figure 1) by visualizing both *halves* of the oval as denoted with a dotted line. The teacher provides goals and objectives of the lesson while targeting learning and problem solving through discourse. Likewise, the role of students to engage in the mathematical content of the lesson through problem solving and discourse is a shared responsibility to nurture both sides of responsibility that will increase the likelihood of mathematical learning. The MCOP^2 framework and measurable factors emphasize that both teacher and student have shared responsibilities within the learning community of the mathematics classroom.

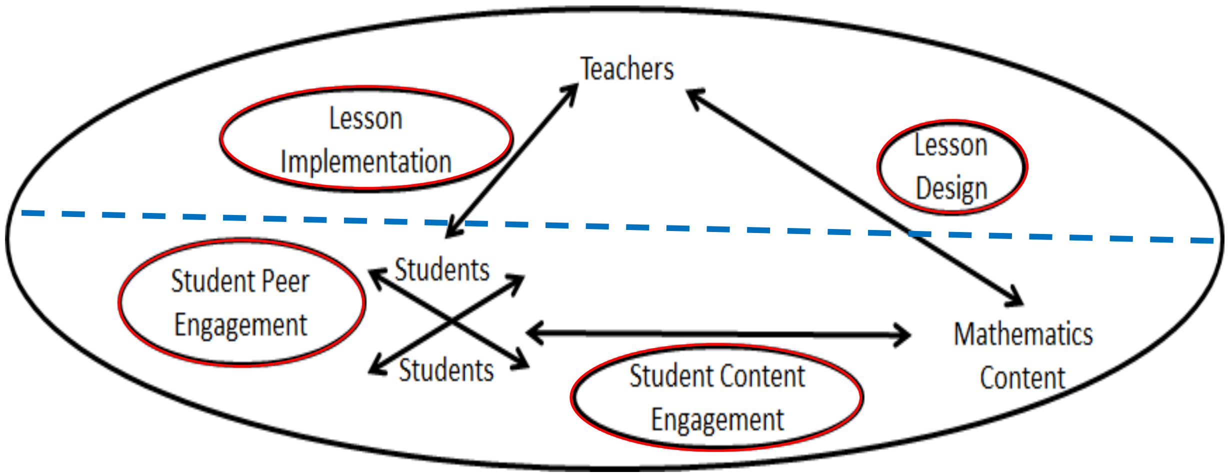

Figure 1. Instruction as Interaction model (Based upon Cohen et al., 2003).

Methodology

The SEMA-TPP aimed to replace a generalist secondary programs form for grade-bearing observations of methods students and teacher with a specific mathematics observation protocol targeting both teacher facilitation and student engagement measures of effective instruction.[1] To support this shift and subsequently address the research questions, the SEMA-TPP collected observational data and survey data for two years, during the 2014-15 and 2015-16 academic calendars. Observations of the delivery of mathematics lessons in 6-12 mathematics classrooms by methods students and student teachers used both observation forms, with the order of form completion alternating between observations. This method was used to increase the reliability between scores on both forms, as well as increase the validity of accurately recording the observation across both forms (Bryman, 2012). The generalist form was used in the determination of student grades, and although MCOP^2 data was collected, it did not impact grades. At the conclusion of Year 1, data from the paired observation forms was presented to the secondary programs faculty. SEMA-TPP faculty moved forward in using each protocol in Year 2 with each form counting as 50% of the observational grades.

[1] The generalist form in use at UA can be found at http://bit.ly/SecObsForm, and the MCOP^2 can be found at http://bit.ly/UA-MCOPP.

Brief Overview of the Results

We address each research question individually. The first question considered (1) What grading scale would be appropriate on the MCOP^2 and correlate well to the grades received on the generalist observation form? Over the two-year study, we examined 59 SEMA-TPP candidates in middle and upper grades mathematics classrooms using both observation forms. Of the 59 candidates, 31 were students enrolled in a methods course, while 28 were student teachers in the subsequent and final term in the program. Analysis of the data yielded a *very strong* correlation between scores on the two forms, shown in Figure 2.

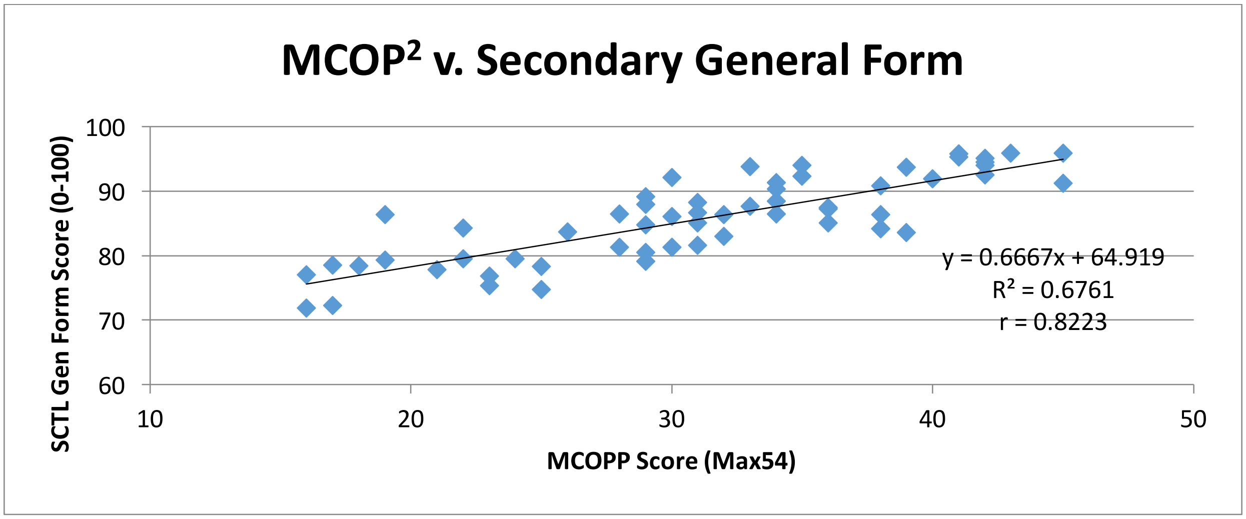

Figure 2. Correlational analysis of the MCOP^2 observation form to the generalist form.

Such a result is sufficient evidence to warrant using either form. On the other hand, this result is heavily reliant on one rater; the rater in this case is the lead author who regularly scored lessons on the generalist form in the C or average range (range during study 72 to 97). Cooperating mathematics teachers, in contrast, rarely scored observations of student teachers less than a mid-B, mostly assigning A's (95% of the time). Thus, the strong correlation of the findings indicate that an accurately scored MCOP^2 rubric will align to A, B, C, D, F letter grades easily, whether used by a teacher, supervisor, or university faculty. Next was to consider what MCOP^2 point total equates to each letter grade A, B, C, D, and F.

In Figure 3, we examine the use of the linear model in Figure 2, while in Figure 4 we present an improved spread across excellence, good, average, and below average (failing) scores. Using only the linear regression model on the MCOP^2 point totals, Figure 3 reveals grades would convert to a range of about 75 to 95. This result aligns to the range of scores that supervising teachers regularly assigned, 80-100, on the generalist forms reduced by five points. Therefore, we decided to examine the MCOP^2 means per item (0.0 to 3.0).

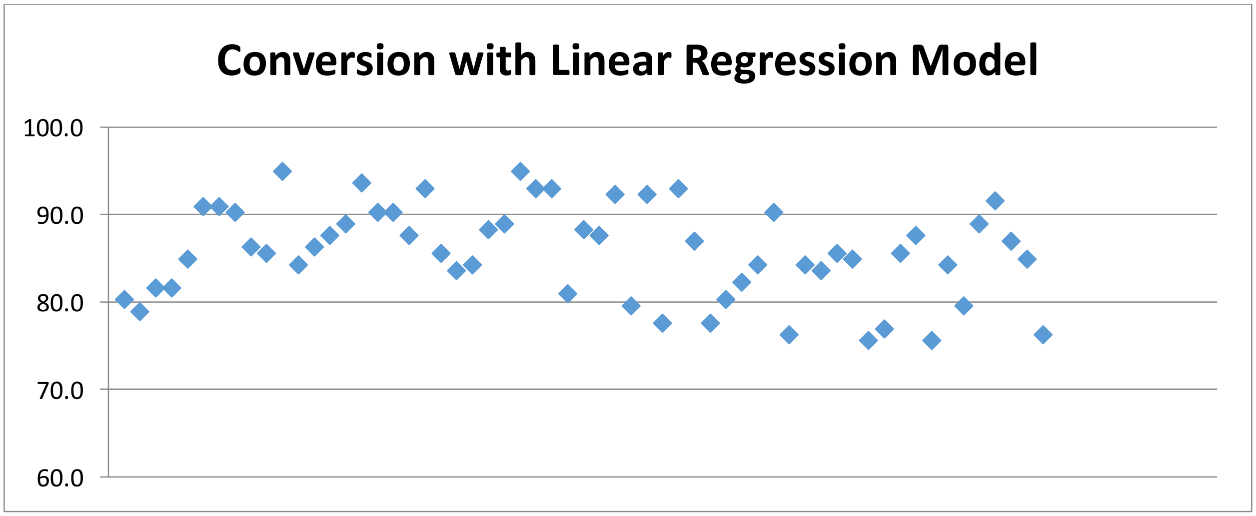

Figure 3. Conversion of MCOP^2 scores using least squares linear model.

We explored a few options and settled on a conversion that is shown in Figure 4 to obtain the desired distribution. Figure 4 demonstrates that the spread of the converted scores, 68 to 100, is very similar in nature to the spread of generalist form scores by the lead author, 72 to 97.

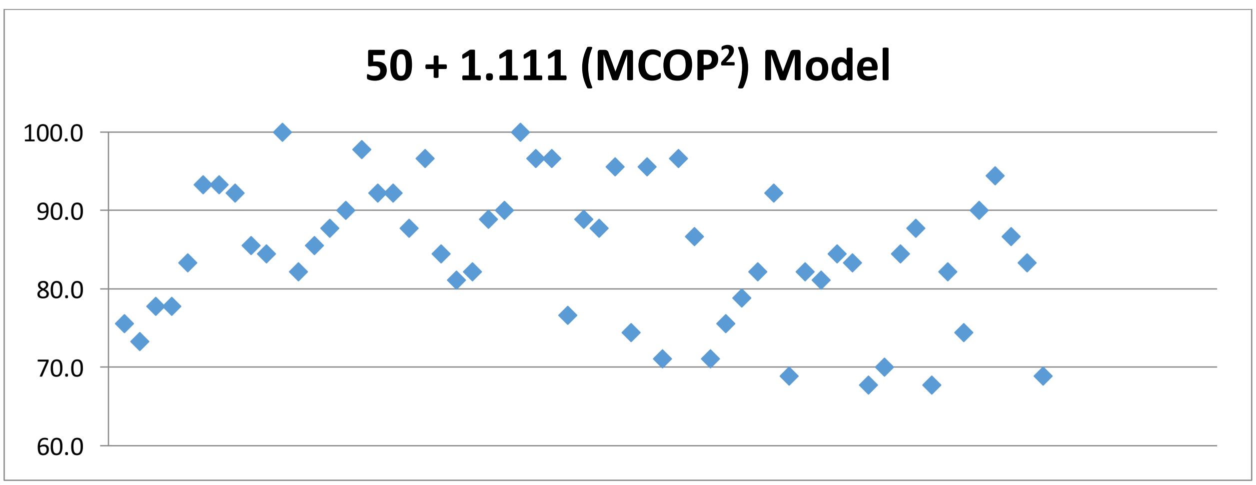

Figure 4. UA SEMA-TPP adopted grade conversion model for the MCOP^2. Notes on conversion: MCOP^2 mean score of 2.5 is equivalent to 100%, an A+; MCOP^2 mean score of 1.0 is equivalent to 70%, a C-.

The raw scores from the MCOP^2 can range in total points from zero to 54. It is unreasonable to expect perfect threes, let alone half twos and half threes from novice teachers. However, programmatically we view a mean of 2.5 as a top score for a preservice teacher designed and delivered lesson and a mean of 1.0 as minimally passing. The range 1.0 to 2.5 on the MCOP^2 maps to a distribution from the mid-60s (failing) to 100 (perfect) for converting to a grade. We have adopted the linear score conversion of *grade*=50+10/9**MCOP^2* (shown in Figure 4) to translate the MCOP2 score to a grade out of 100 points, revealing excellence, good, average, and in need of improvement to pass.

Our second research question was, (2) How do preservice teachers perceive the MCOP^2 as their grade-determining observation protocol, as opposed to the generalist observation form? The resulting MCOP^2 grades were higher or almost equal than the general form grades about 2/3 of the time. Eighty-three percent (n=49 of 59) of preservice teachers reported, through online anonymous surveys, they preferred the MCOP^2 score because they knew what to improve on for the next observation whereas the generalist form was not specific enough without written feedback or discussion. This feedback was very telling; they preferred knowing exactly their role and their students' roles in a formally observed lesson as it was outlined in the MCOP^2. A large portion (n=25 of 28) said they preferred the MCOP^2 during their student teaching so that *only mathematics teachers* would score and determine their grades. About half of student teachers are observed by out-of-field teachers within schools for upwards of half their observational scores during their student teaching internship. This practice has since changed to only formative non-grade bearing feedback by out-of-field teachers. MTE-P partners have indicated this out-of-field observation practice is common even though it does not provide feedback to the preservice teachers or program faculty regarding the implementation of high quality mathematics lessons.

We also set out to study, (3) Does preparing preservice teachers to consider the MCOP^2 in their planning of formal observation lessons improve the quality of the lessons than prior to the MCOP^2 implementation? To answer this, we examined the *lesson plan* scores of all formal observations during the two years of data collection of all methods students (student teachers were not scored on lesson plans). We then looked back to the prior two years of lesson plan grades of generalist form scored observations of methods students of lessons implemented. We found that 26 of 31 (84%) method student lesson plans from two years of MCOP^2 were scored higher than in the two years prior to MCOP^2. This indicates a higher quality in lesson planning when the MCOP^2 is used as an observation protocol. When comparing the pre-MCOP^2 era observation scores on the generalist form to the observations with the generalist form during the MCOP^2 use, the same 84% of observations scored better. Hence, we conclude that both planning and enactment was clearly better with the MCOP^2 use in our program.

Conclusion

Our conclusions of this preliminary work to begin and understand the implementation of the MCOP^2 in the UA SEMA-TPP program reside in our fourth research question, (4) What are the impacts for both students and program to use the generalist form as a non-grade-bearing, end-of-semester, summative form, and the MCOP^2 as the exclusive grade-determining observation protocol for both methods students and student teachers? A unit, college, or program can and should use generalist summative tools for analyzing large-scale factors as overall university/college preparation, secondary programs preparation, or state-level preparation. On the other hand, at the level in which we evaluate and assess our teacher candidates during methods and student teaching, the $MCOP^2$ results clearly promote better designed lessons, and stronger implementation of those lessons. In addition, teacher candidates prefer the $MCOP^2$ to help because of the detailed information provided to guide their professional development and the more accurate determine their grades for formal observations of teaching.

Our institutional colleagues have recognized this work and are now following on the heels of the successes of the SEMA-TPP. More impacted are the local cooperating teachers who now find great value in a well-defined rubric measuring both sides of their responsibilities, the mathematics classroom itself, and supporting the student teacher to achieve this target. Moreover, the cooperating teachers do not feel pressured to give higher grades. Some teachers have mentioned using the $MCOP^2$ helps them now look for certain practices of themselves and their students in their normal classroom daily operation. This impact on cooperating teacher instructional practices implicitly from classroom teachers using the $MCOP^2$ to evaluate preservice teachers is an intriguing area for future research.

Drawbacks and Limitations

We recognize not all programs can implement the practices at UA as many out-of-field teachers evaluate methods students or student teachers, and some programs do not have a year of strong preparatory content, pedagogy, and clinical field experiences before methods and student teaching. These practices for preparation of secondary mathematics teachers at UA are our implementation of the recommendations of MET and MET II, structures intended to best serve both preservice teachers and the students in secondary schools in which they will teach. We are concerned that the practice of evaluation done by out-of-field educators works against the efforts to transform mathematics teacher preparation in the eyes of the public and stakeholders. High stakes testing like the edTPA are here because the field of teacher preparation has allowed a perception to emerge that we produce an unacceptable percentage of unprepared and unqualified credentialed teachers. We question the ethical rationale of any practice that contributes to the public perception of weak teacher preparation, a problem heightened in mathematics due to the generally negative views of mathematics in the U.S.

Next Steps

Our next steps on our program transformation at UA SEMA-TPP center around three items. First, we aim to begin work on tying student achievement measures to the $MCOP^2$. This is a massive endeavor requiring funding for a large-scale study. Second, we aim to begin analyzing our NCTM SPA data set to extract programmatic variables that influence $MCOP^2$ scores and make changes, additions, and deletions to the programmatic structure where needed. Lastly, we aim to begin work with our cooperating and mentor teachers with the $MCOP^2$ as previously mentioned.

We hope that the MTE-P community welcomes this instrument and finds it useful in aiding the similar transformation of their secondary mathematics teacher preparation program, especially for evaluating methods students and student teachers in the mathematics classroom.

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Variability in Clinical Experiences across the California State Universities

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California State University Fullerton has participated in the national-level Mathematics Teacher Education Partnership (MTE-P) since its inception. However, additional members from five other CSU campuses joined MTE-P at the Annual Conference in Milwaukee, June 2014. The feedback from the MTE-P conference attendees and the innovative approaches to research on best practices that MTE-P embodies led the CSU Office of the Chancellor to open the invitation for participation of all 22 CSU campuses with teacher preparation programs. In addition, the Chancellor's Office began sponsoring separate CSU MTE-P events in order to focus the approach to the unique qualities of the California teacher preparation context. This created the largest team in the MTE-P organization.

As part of the CSU MTE-P structure, a Measures Group was formed internal to the CSU team. The purpose of the group was to collect and organize data from across the CSU system and determine what, if any, measures could be implemented across the CSU teacher preparation programs. Analysis of the data collected could be used to identify best practices and areas for improvement.

The first step in the process was to investigate how similar or different teacher preparation programs were within the CSU system. The Measures Group considered various components of teacher preparation programs (e.g. methods courses, field experiences) and developed a survey to collect information about the specific components. The Measures Group posited that common measures across programs could lead to highly variable results based on programmatic structures as opposed to differences in fundamental programmatic approaches to teacher preparation. In addition, the manner in which the measures are applied could vary tremendously based on structures as well.

These same issues related to structural differences across programs are present in the larger MTE-P community as well. California is somewhat unique in that teacher preparation programs are post-baccalaureate programs, with the exception of the rare "blended" programs in which students can take some teacher preparation coursework during their undergraduate years. The vast majority of other states have teacher preparation programs at the

Lawler, B. R., Ronau, R. N., & Mohr-Schroeder, M. J. (Eds.). (2016). *Proceedings of the fifth annual Mathematics Teacher Education Partnership conference*. Washington, DC: Association of Public Land-grant Universities.

undergraduate level such that students can graduate with a degree and be recommended for a teaching credential simultaneously. Fieldwork components are different lengths and have different intensities. Content methods coursework varies in number and curricular depth of math content. Consequently, whatever the CSU MTE-P Measure Groups can learn from its investigation can be applied, in theory, to the larger MTE-P entity.

Description

To collect information about the structures and practices across CSU teacher preparation program, the Measures Group created a survey that was distributed to CSU MTE-P representatives at all 22 campuses. The survey included items related to the campus's subject matter waiver program for foundational level and full math credentials, whether the campus is on a semester or quarter calendar, details about the math methods coursework, the field experience, mentor teachers, university supervisors, frequency of observations, observation protocols, and student teaching evaluations. The survey was distributed through an online site and data was amassed in the same password-protected online environment. The raw data was translated into pie charts and bar graphs and later presented to the campus representatives at a CSU MTE-P meeting during which adjustments to the raw data were made due to original misunderstandings of the questions or simple errors in responses. Once the data was accurate, the Measures group shared it again with the CSU MTE-P community and planned to present it to the larger MTE-P membership.

Results

Of the 22 campuses surveyed, 18 responded. The survey questions and their responses are reported in Table 1.

Table 1
Survey Results of Secondary Mathematics Teacher Preparation Programs in the CSU

Question	#	Response
1. Does your campus have an approved waiver program for foundational level mathematics?	11 7	No Yes
2. Does your campus use a semester schedule?	4 14	No Yes
3. How long is your student teaching experience?	4 9 1 2 1	1 Semester 2 Semesters 1 quarter 2 quarters 3 quarters
4. Do your teacher candidates (TCs) take a math methods course concurrent with their student teaching experience?	4 14	No Yes

Question	#	Response
5. How many units is the methods course, if you have one?	1	1.5 units
	4	2 units
	8	3 units
	4	4 quarter units
	1	5 quarter units
6. How many mentor teachers do your teacher candidates student teach with?	10	1 mentor teacher
	8	2 mentor teachers
7. What are your Master/Mentor Teachers paid for working with teacher candidates per semester? Choose the closest match.	7	Nothing
	11	\$50–\$250
8. During the teacher candidate's student teaching experience, are they required to be supervised by someone who is/was a credentialed teacher of secondary math?	6	Yes
	12	No
9. How often are your teacher candidates formally observed during the first semester?	1	Once a semester
	4	Twice a sem.
	1	Three times
	7	Four times
	1	Five times
	1	Six times
	1	Eight times
	1	Ten times
10. How often are your teacher candidates formally observed during the second semester?	1	Twice a sem.
	2	Three times
	4	Four times
	3	Five times
	5	Six times
	2	Eight times
11. When the teacher candidate is observed, what sort of observation protocol is used? General? Subject specific?	9	General
	4	Both
	4	Neither

Conclusion

From collecting information from all CSU campuses that offer teacher preparation programs, we learned that there was high variability in all aspects of mathematics teacher preparation clinical experiences. Key components included the number of units required in mathematics methods coursework, the number of hours and semesters/quarters of fieldwork experiences, the number of mentor teachers and supervisors a candidate has throughout the teacher preparation program, the qualifications of mentor teachers and supervisors, the number of formal observations supervisors make each quarter/semester, and the amount of money (if any) mentor teachers are paid. While some components on the surface may seem inconsequential, for example the amount of money mentor teachers are paid, all components play a role in the development of a teaching candidate such as recruitment of mentor teachers in this example. Consequently, the results of measures utilized by MTE-P, Research Action Clusters (RAC), and sub-RACs must be carefully analyzed in light of this programmatic variability.

As a CSU local partnership, the Chancellor's Office expressed interest in identifying common measures to be used across the CSU teacher preparation programs to determine program effectiveness. However, with such tremendous variability in the programs, it would be difficult to make program by program effectiveness comparisons before determining how different program configurations impact measures outcomes.

However, new California Commission on Teacher Credentialing teacher preparation program standards for clinical experiences will reduce the variability in many program elements, but not all (Commission on Teacher Credentialing, 2016). For example, a minimum of 600 hours of fieldwork will be required across the arc of each post-baccalaureate teacher preparation program. In addition, each candidate must be formally observed 4 times each quarter or 6 times each semester by a supervisor who has expertise in the subject area the candidate is teaching. While the new program standards reduce the variance in many aspects of the teacher preparation programs, others remain such as those associated with methods coursework.

If such large-scale variability exists within the CSU system, imagine the scale across the MTE-P participating universities. While all RACs will be using several common MTE-P measures, we must be mindful of what the outcomes indicate and to what extent they are the result of "best practices" or programmatic differences.

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Using Improvement Science to Increase Mathematical Learning through Co-Planning and Co-Teaching

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No matter what the scenario is within the field of mathematics education, one point that all teachers should agree upon is that providing opportunities for students' learning to occur should be an ultimate goal of teaching (Bransford, Brown, & Cocking, 2004; Shulman, 1999). Therefore, teacher preparation programs are challenged to equip teacher candidates with the skills needed to cultivate learning, while being cognizant of the fact that teacher candidates are also engaged in the learning process, because they are apprentices of teaching (Collins, Brown & Newman, 1988). Thus, to model the desired practices that can promote learning, teacher preparation programs are challenged to make explicit connections between coursework and field experiences for their teacher candidates (Darling-Hammond & Bransford, 2005; Sowder, 2007).

As a means to place a focus on learning in teacher education programs, the use of co-planning and co-teaching (CPCT) strategies can be employed. Co-teaching is a pedagogical practice that encourages collaboration and communication between teacher candidates and their mentor teachers who share a common space in the organization, delivery, and assessment of instruction (Bacharch, Heck, & Dahlberg, 2010). When CPCT is employed, teacher candidates are valued as teachers in the classroom from the inception of the field experiences. There are various co-teaching strategies, including: *one teach one observe*, *one teach one assist*, *station teaching*, *parallel teaching*, *alternative teaching*, and *teaming* (Friend, Cook, Hurley-Chamberlain, & Shamberger, 2010). During the co-planning meetings, which occurs before the co-taught lessons, the teacher candidates and their mentors reflect on the nature of tasks to be used, the mathematical discourse that would be encouraged, means to make mathematical connections, and instructional strategies that can be employed. Thus, employing CPCT during field experiences can be used to promote a focus on students' learning, while providing learning opportunities for both the teacher candidates and their mentors.

Traditionally, in the field of mathematics education research, we obtain results from empirical studies of students learning after the students have progressed to another grade

Lawler, B. R., Ronau, R. N., & Mohr-Schroeder, M. J. (Eds.). (2016). *Proceedings of the fifth annual Mathematics Teacher Education Partnership conference*. Washington, DC: Association of Public Land-grant Universities.

level, so the students who were actually studied can never benefit from changes in instructional practice indicated by the study. Improvement science offers an alternative to an empirical research design, because it is designed to study practices rapidly, make appropriate changes immediately, and to engage individuals in an ongoing cycle of improvement (Bryk, Gomez, Grunow, and LeMahieu, 2015). For example, during a medical surgery, if complications arose during the surgery, the surgeons may make immediate changes to their planned procedures in order to minimize complications while seeking to preserve their patient's life. In education, timeliness of change may not be life threatening, but making changes to practice when current actions fall short of desired results is the cornerstone of good teaching. Thus, we hypothesize that teacher candidates and mentor teachers will place a greater focus on learning by using CPCT when improvement science research design is employed.

Purpose

This study seeks to describe the extent teacher candidates and their mentors placed a focus on students' mathematics learning, when CPCT strategies were used and improvement science research design was employed. Therefore, we sought to answer the following question: *In what ways does co-planning and co-teaching strategies assist the mentor teachers and teacher candidates to focus their work on students' learning of mathematics?*

Related Literature

The core responsibilities of teacher education programs are to develop teacher candidates' pedagogical content knowledge, and to promote strategies that can facilitate students learning (Feiman-Nemser, 2001). Field experiences are intended to serve these purposes, but mentor teachers often view these experiences mainly as ways for teacher candidates to develop their classroom management skills, and become acculturated with didactical norms and activities (Leatham & Peterson, 2010). To address the shortcomings of traditional field experiences, co-teaching strategies can be employed. Co-teaching can promote professional growth opportunities, enhance teachers' understanding of the curriculum, improve students with disabilities academic performance, and increase teachers' job satisfaction (Bacharch, Heck & Dahlberg, 2010; Dieker, 1998; Dieker & Murawski, 2003; Idol, 2006; Rea, McLaughlin & Walter-Thomas, 2002; Rice & Zigmond, 2000). Nevertheless, professional development training is vital when seeking to implement co-teaching (Cardullo & Forsythe, 2013). During the professional development training, mentor teachers and teacher candidates learn about various co-teaching strategies, and reflect on how roles and responsibilities may change depending on which strategy will be utilized. Additionally, teacher candidates and their mentors are provided an opportunity to interact with each other, and address challenges that might be encountered (e.g., approaches to cultivate productive consultations) (Feiman-Nemser, 2001).

Co-planning lessons, which are a primary component of co-teaching, benefit the teacher candidates and their mentor teachers (Mastropieri, Scruggs, Graetz, Norland, Gardizi, & Mcduffie, 2005; Scruggs, Mastropieri, & McDuffie, 2007). Although there are some challenges that can hinder effective co-planning (e.g., insufficient time), if done well, co-planning can facilitate proactive discussions across the curriculum, and about a variety of instructional practices that can be used to facilitate students' learning (Dieker & Murawski, 2003).

Connections to Institutional Transformation

Since 2012, the Network Improvement Community (NIC) that focused on CPCT during clinical experiences, which is a sub-group within the clinical experiences research action cluster (RAC), has sought to design professional development modules and instruments to measure the nature of implementation of CPCT. Additionally, the NIC have sought to use improvement science systematic process (Plan-Do-Study-Act (PDSA) cycles) to improve field experiences and promoting students' success. Overtime, a focus on student learning has gained momentum and was intensified. Currently our NIC is comprised of 11 universities from 6 different states. Members of the NIC vary in their implementation of CPCT, some of our participating research sites are in the beginning stages of institutionalizing the practice of CPCT, while others have fully implemented CPCT into their clinical experiences.

Method

In this pilot study, we used the systematic process of improvement science (Plan-Do-Study Act [PDSA]) to examine how CPCT can be used during field experiences to place a focus on learning. More particularly, we implemented the CPCT Apprenticeship Model for Learning (Brosnan, Jaede, Brownstein, & Stroot, 2014) in which mentor teachers initially provide guidance, and over time teacher candidates and mentor teachers share instructional responsibilities. During the 2014-2016 academic years, we gathered quantitative and qualitative data using multiple instruments (pre-survey, just-in-time survey, and focus groups). The quantitative data were analyzed using descriptive statistics and the qualitative data were analyzed using thematic analysis. Highlights of the various PDSA phases are described below.

Plan: Focus on Learning. Inspired by mantra oft-repeated by Brosnan, "We will no longer teach teachers how to teach. Rather, we will teach teachers how to get students to learn," we planned to implement CPCT during field experiences and encouraged both the mentor teachers and teacher candidates to place an explicit focus on students' learning. To help our mentor teachers and teacher candidates focus on learning, we asked the instructional pair to use the following three questions as a guide during their co-planning:

- What do students need to learn?
- How will you know if they learned?
- In what tasks will students engage to ensure learning happens?

By focusing on learning, the mentor teachers and teacher candidates were also asked to establish clear mathematical goals, and to pose tasks that allowed for diverse approaches to solve the problem, multiple entrée points, and multiple solutions to the tasks provided. The mentor teachers and teacher candidates were also encouraged to exhibit the Standards for Mathematical Practice (National Governors Association, 2010) within their everyday practice.

Do: Co-Planning and Co-Teaching (CPCT)

During the *do* phase of the cycle, each mentor teacher and teacher candidate pair were required to attend a professional development training and establish regular meeting times to conduct their co-planning sessions. A topic was identified for these planning meetings and each participant was asked to bring ideas about the types of tasks in which they might engage their students to reach the learning needs of the class. At the beginning of the semester, the mentor teachers were responsible for most of the instructional decisions, but they were asked to explain their thinking and instructional decisions. Over time, using a guided approach, the mentor teachers and teacher candidates started to share the responsibility of contributing their ideas about instruction. During the lesson, one person was encouraged to take the lead to establish the task, and then both teacher candidates and their mentors circulated the room looking for evidence of student learning. Continuous assessment was a part of all enacted lessons. Using CPCT provided increased opportunities for both instructional pairs to engage in formative assessment measures.

University representatives also collected data about the nature of CPCT from the teacher candidates and their mentors. Data were collected via the pre-survey (Oloff-Lewis & Biagetti, 2014), just–in-time survey (Sears & Maynor, 2014), and focus group interview (Brosnan et al., 2014). The pre-survey provided insights into respondents' perspectives about Common Core Content Standards and Standards for Mathematical Practice; strategies used to teach diverse learners perspectives about CPCT; and assessment practices that are utilized. The just-in-time survey asked respondents to rate how frequently they used CPCT during their field experiences, the extent CPCT was beneficial, the extent the communication between instructional pairs were productive, and the frequency of various instructional norms occurrences. Additionally, the mentor teachers were asked to participate in a focus group interview that documented their perspectives on the CPCT process.

Study

During the *study* phase, we reviewed teacher candidates and mentor teacher responses to the various instruments, and examined the extent the focus on learning during enacted lessons went as planned. We also examined their perspective about how CPCT contributed to students learning, and documented changes in their perspectives over time.

Based on the data gathered from the pre-survey, initial concerns existed relative to how instruction will be shared and the extent interns had sufficient experience to work independently as well as exhibit effective classroom management practices. However, these perceptions changed overtime based on the relationship building activities that occurred during the professional development training and subsequent CPCT interactions. Based on the data garnered from the just-in-time survey and focus group, mentors reported that using CPCT to focus on learning influenced the teacher candidates to feel more prepared and more confident to teach. Furthermore, in the era of accountability, the mentor teaches felt more at ease since they were still given a degree of control of their class progression, and was able to help teacher candidates in facilitating scaffolding activities, and acquiring skills of the discipline.

More particularly, the mentor teachers focus group interviews revealed four major implications of using CPCT to focus on students learning: their instructional practices improved, quality of mentorship was refined, the teacher candidates were better prepared, and students' academic performance was improved. The mentor teachers claimed that they became better teachers and that they became better mentors. In addition, they found that the teacher candidates had more opportunities to learn skills of the discipline thereby resulting in better-prepared teachers. And finally, they claimed that the students were the ultimate benefactors because of the focus on learning (Brosnan et al., 2014). Thus, the focus of learning during CPCT was perceived to be beneficial in multiple ways.

Act: Reflect on the Process

Based on our findings, we reflected on the results and considered means to further promote students learning. We noticed that the teacher candidates and their mentor teacher reflection focused more on data drawn from formative assessments, and made students learning a more dominant focus of their reflection. This was indeed a shift from previous norms, in which teacher centered reflections were quite evident. We also noticed that the focus on learning strengthened communication channels between the instructional pairs because they sought to collaborate to support student learning, rather than concentrating solely on summative assessment measures of the teacher candidates' actions during field experiences. The variance among teacher candidates' and mentor teachers' conceptions of learning, and teaching practices, we seek to scale up our focus on learning at other institutions through our future PDSA cycles, and will further unpack the following questions.

- What does the evidence of learning we collect tell us about what students, teacher candidates, mentor teachers, know and are able to do?
- What counts as learning from the lens of the teacher candidates and mentor teachers?
- How do teacher candidates and mentor teachers use data gathered on student learning to plan for future learning?

Conclusion

From this study, we learned that placing a focus on learning during CPCT activities increased opportunities for the mentor teachers and teacher candidates to collaborate and promote student success. We also noticed that implementing a change concept can take time, so detailed planning is vital to ensure the ideas presented are viable and sustainable. We noticed mentor teachers' perspectives about CPCT changed overtime. They saw value in welcoming teacher candidates as teachers from the onset. Collaborative efforts, which are evident when CPCT strategies are employed, can seek to maximize learning opportunities, and can be beneficial for all parties involved.

Furthermore, the collaborative partnership among MTE-P NIC members provided an opportunity to engage in research, while systematically seeking to positively transform field experiences using CPCT. Due to the partnership, the workload was shared; local school partners became aware of the success patterns and inquired about means to include CPCT within field experiences within their district. Therefore, this pilot study has helped our NIC move closer to meeting several of our goals to substantiate CPCT as a viable strategy to improve teacher learning and student mathematics learning. In the future, we intend to continue this work and implement it in a greater number of sites.

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Co-Planning Strategies to Support Intern Development

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Researchers consistently state that co-planning is critical within a co-teaching context (e.g., Howard & Potts, 2009; Magiera, Smith, Zigmond, & Gebauer, 2005). Unfortunately, the literature provides little guidance on how co-teachers should co-plan together effectively. In order to provide some direction for co-planning, we first explored an adaptation of co-teaching strategies to co-planning. Working with mentor teachers, we further defined co-planning strategies and then tested the strategies with mentor teachers and interns.

Co-planning is particularly important during pre-service teachers' internship experiences. Interns, given their lack of teaching experience, are likely to have more difficulty than experienced teachers being flexible and attentive to student needs as they plan for instruction (Borko, Livingston, & Shavelson, 1990; Leinhardt & Greeno, 1986; Livingston & Borko, 1989). At the same time, interns may be creating some of their first lesson plans designed for actual students in classrooms rather than plans for lessons with hypothetical students. Interns are also facing a rapid escalation in the rate at which they need to prepare lessons – often transitioning from writing several in a semester to writing several each day. Further complicating an already challenging situation is that fact that interns are planning and implementing these lessons in a setting in which their clinical teacher sets the classroom norms and the expectations for quality instruction. Added to these challenges is the fact that many experienced teachers may not write detailed lesson plans, leaving interns little access to the planning decisions made by their mentor teachers. Having interns and mentors co-plan lessons has the potential to aid interns in the transition from mathematics education students to mathematics educators and help ensure that plans reflect norms acceptable to the mentor teacher.

Theoretical Support

Our work with co-teaching and co-planning during pre-service teachers' internship experiences is grounded in Lave's (1991) construct of situated learning. As interns go out into the field, their learning moves from a predominately academic experience to an apprenticeship within a community of practice. In such a setting the working relationship between intern and mentor teacher becomes a major determining factor in the intern's ability to participate productively and collaboratively in the practice of classroom teaching. In our work we consider ways to expand traditional visions of this working relationship between intern and mentor, envisioning mentor and intern as collaborators in classroom planning and instruction.

Connections to the MTE Partnership

The purpose of the Mathematics Teacher Education (MTE) Partnership is to improve secondary mathematics teacher education. Internship experiences are a critical component of teacher education. The range of experiences during the internship may be described as an iterative cycle that encompasses observing, planning, teaching, assessment, and reflection. In our past experiences working with clinical placements, the implementation of this cycle has taken a very traditional route where the intern is provided with a set of course standards, a pacing guide, and possibly their mentor's instructional resources, and they are charged to create a lesson plan independently. The mentor critiques this lesson plan once it is written. Frequently this lesson plan does not meet the mentor's expectations for quality instruction; the intern then scrambles to revise the lesson plan based on the mentor's critique. If the lesson plan is still not adequate, the planning and critique process is repeated. Eventually, the lesson plan is approved, and the intern has survived the planning cycle. However, there may now be insufficient time to reflect on the planning cycle and conceptualize quality instruction. Then the cycle begins again.

In an effort to produce more effective secondary mathematics teachers, we now emphasize a 1:1 co-teaching model that emphasizes feedback and reflection throughout the iterative cycle described above. Rather than being sent off to plan in isolation, the mentor and intern plan together, each bringing his or her individual knowledge and skill to the planning process. Planning decisions are made with the goal of optimizing student learning; instructional strategies (including co-teaching strategies) are selected appropriately; and, together, the mentor and intern reflect about instruction and the effect on student learning. Throughout this process the intern assumes an increasing responsibility for planning and instruction as the internship progresses but, unlike the "sink or swim" paradigm presented above, interns are provided with continual support.

Description of the ECU Project

The mathematics education program at East Carolina University has been involved with co-teaching since the fall of 2013. Throughout this process we have been working with the MTE Partnership within the Clinical Experiences Research Action Cluster (RAC). As part of the Clinical Experiences RAC, we have been involved with the co-planning/co-teaching sub-RAC. Despite yearly trainings related to co-teaching, our clinical teachers and interns reported continued difficulty with exactly how to co-plan together and effectively increase the interns' responsibility for planning and instruction. Our solution to this issue was to draw upon our combined experience teaching high school mathematics and supervising high school mathematics internships to draft six specific co-planning strategies.

Bacharach, Heck, & Dahlberg (2010) and Murawski & Spencer (2011) outline specific co-teaching practices that have successfully supported mentor teachers' in shifting from the traditional student teaching model to a co-teaching model. Analogous to these co-teaching practices, our goal was to develop specific co-planning practices for mentor teachers and interns to use for effective co-planning. We began this process by translating several co-teaching strategies into a similar collaboration process for co-planning. For example, we thought about what the One Teach, One Assist co-teaching strategy would look like for co-planning, which resulted in the One Plans, One Assists co-planning strategy. After defining each strategy we worked with mentor teachers to further refine them and pilot them with mentor teachers and interns. The resulting six co-teaching strategies are described in Table 1.

These strategies parallel the co-teaching strategies, but are not intended to be paired with any specific co-teaching strategy. They also should not be viewed as hierarchical, although some strategies require a more established relationship and rapport between the clinical teacher and intern than others. Consequently, some strategies are best used earlier or later in the internship experience. Similar to co-teaching strategies they should be utilized to best meet the needs of the clinical teacher and intern in effectively designing instruction to support student learning.

Methods Used to Address the Issue

Our first Plan, Do, Study, Act (PDSA) cycle (Bryk, Gomez, Grunow, & LeMahieu, 2015) spanned the academic years 2014-2015 and 2015-2016. We developed training materials for co-planning and co-teaching, and conducted professional development with our clinical teachers and interns. Based on focus group interview feedback from 2014-2015, we revised our materials to include more activities focused on implementation of the co-planning strategies between clinical teachers and interns during the professional development. During the 2015-2016 academic year we were able to pilot data collection related to implementation of co-planning and co-teaching strategies. We were interested to learn if clinical teachers and interns were using the co-planning strategies.

These co-planning strategies are currently theoretical constructs that describe specific ways that clinical teachers and interns can operationalize the co-planning process. We have seen promising anecdotal data from classroom observations and exit surveys completed by clinical teachers and interns during the first PDSA cycle, and we are using this information to implement more strategic and focused data collection and analysis for our second PDSA cycle.

Table 1.
Co-Planning Strategies

Co-Planning Strategy	Description	Adapted Co-Teaching Strategy
One Plans, One Assists	Each co-teacher brings a portion of the lesson, although one clearly has the main responsibility. The team works jointly on final planning.	One Teach, One Assist
Partner Planning	Co-teachers take responsibility for about half of the components of the lesson plan. Then they complete the plan collaboratively.	Station Teaching
One Reflects, One Plans	One co-teacher thinks aloud about the main parts of the lesson and the intern writes the plan.	Alternative Teaching
One Plans, One Reacts	One co-teacher plans and the other provides feedback on the plan.	One Teach, One Observe
Parallel Planning	Each member of the co-teaching team develops a lesson plan and the two bring them together for discussion and integration.	Parallel Teaching
Team Planning	Both teachers actively plan at the same time and in the same space with no clear distinction of who takes leadership.	Team Teaching

Results

Our first PDSA cycle was considered a pilot study, and we received positive indications that clinical teachers and interns were using the co-planning strategies to design instruction. In the words of one clinical teacher,

> We participated in co-planning activities where I provided the lessons and the intern provided the activities, as well as where she provided the lesson and I provided the activities. We developed thinking maps together during co-planning sessions. She created full lessons that I provided input on. We determined together the roles for co-teaching. (PDSA cycle 1, Mentor Exit Survey, 2016)

This quote does not cite a specific co-planning strategy by name, but when compared to the definitions from Table 1, there is evidence of *One Plans, One Assists*/*Partner Planning*, *One Plans, One Reacts*, and *Team Planning*.

Interns also noted successful use of the co-planning strategies. According to one intern,

> At first she [the clinical teacher] was the main planner and teacher. She told me what she did, how she did it, and her thought process. When I took over, she assisted me. She helped me think through planning and what my students

> needed to know and how I should deliver it. (PDSA cycle 1, Intern Exit Survey, 2016)

This quote suggests the use of *One Plans, One Assists* along with *One Reflects, One Plans* with the role of the clinical teacher and intern transitioning as the internship progressed. The intern also highlights the criticality of the clinical teacher making explicit for the intern the implicit decision-making process during planning and instruction.

Impact on local partnership

The quotes above illustrate that clinical teachers and interns not only utilized specific co-planning throughout the internship, but also noted the benefits of co-planning for themselves and their students. As a result of our work with the MTE Partnership and within our program area at East Carolina University, the co-planning strategies are now embedded in our College of Education co-teaching training across all program areas. These strategies have also been shared with our sub-RAC, and we are now refining the training materials for wider dissemination with our RAC and the MTE Partnership at large.

Contribution to MTE Partnership

Two member institutions of our sub-RAC have invited us to conduct workshops for their clinical teachers and interns. In October 2105 and July 2016, Dr. Cayton and Dr. Grady visited the University of South Florida in Tampa to work with Dr. Ruthmae Sears and the Helios STEM Middle School Residency Program (www.usf.edu/education/research/anchin/teacher-initiatives/preservice-teachers/helios-ms-stem-residency.aspx). We were joined by Dr. Patti Brosnan (Ohio State University) to conduct a one-day workshop for co-planning and co-teaching with clinical teachers and interns for middle grades math and science. In August 2016, we worked with Dr. Jennifer Oloff-Lewis and the Residency in Secondary Education program (www.csuchico.edu/soe/rise) at California State University-Chico. Here we worked with secondary clinical teachers and residents across content areas on implementing the six co-planning strategies mentioned above. As a result of our work at CSU-Chico, we are developing an online module for co-planning that will complement the online co-teaching module currently utilized in the RiSE program. The goal is for these CPCT training modules to be made widely available to MTE Partnership schools and beyond.

Next steps

We are currently in our second PDSA cycle (2016-2017) utilizing the co-planning strategies. Based on the first cycle, we have revised our data collection tools to align with our updated research questions:

- To what extent does the training influence implementation of CPCT?
- To what extent is CPCT being implemented?

- What are perceptions about CPCT from various stakeholders (administrators, mentors, pre-service teachers, university supervisors)?

Our data collection tools include pre-surveys, a co-teaching observation protocol, a survey of strategies used, just in time surveys, and exit surveys. Looking ahead to the third PDSA cycle, we hope to examine implications of CPCT on pre-service teachers' practices, classroom instruction, agency and disposition. We also intend create a data dashboard across institutions with our sub-RAC that have been implementing CPCT throughout PDSA Cycles 1 and 2. We are currently refining our training modules for CPCT for wider dissemination within not only our RAC, but also the MTE-Partnership at large.

For More Information

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Support Systems of Early Career Secondary Mathematics Teachers

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Abstract

This study reports findings from a preliminary survey of mathematics teachers who are in a teacher preparation program or serving in their first three years of teaching. The main objective of the survey was to gather information about how early career teachers are being supported that would inform initiatives aimed at improving teacher retention rates. The survey data focused on what types of activities teachers are participating in, their perceptions of these activities, and how the activities influenced their teaching practice. Additional questions focused on support from professional learning communities, administrators, universities, overall job satisfaction, and how long teachers plan to stay teaching.

CSU Chico Program RiSE: Analysis of the First Recruitment Cycle

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Funded by the US Department of Education, the focus of PRISMS is to promote rural improvement in the subjects of mathematics and science for secondary schools across the nation. RiSE, Residency in Secondary Education, one of two programs supported by PRISMS at California State University – Chico, is an accelerated 12 to 18-month graduate program that combines a Master of Arts in Education and a teaching credential. As the recruiter, my primary role is to utilize innovative and results-driven methods to attract a broad and diverse applicant pool.

Through my work experience, as well as my involvement in the MATH Research Action Cluster, I've had the opportunity to experiment with different marketing strategies and recruitment tools. Here I share the techniques I've found most useful in my practice, drawn from those detailed in the nine modules of the *Secondary Mathematics Teacher Recruitment Campaign Implementation Guide* (Ranta, 2015).

Chico's Recruitment Campaign

Ideally, a successful recruitment campaign starts with a comprehensive approach that incorporates the concepts outlined in Modules 1-4. However, limited funding and an abbreviated timeline don't always allow for extensive planning and research prior to launching a campaign. Additionally, at the time I began my recruitment efforts, the grant already had its branding in place. In other words, as is often the case with project management, I had to hit the ground running and prioritize a quick launch. That being said, I concentrate on Modules 5-9, including Social Media, Public Relations, Paid Broadcast Media, Website Identity, and eventually Evaluation.

Module 5, which focuses on Social Media, asserts that the most popular platform is Facebook. With its widening popularity, social media has seen a rapid growth in audience diversity, making it an even more viable tool for recruitment and a good starting point for many organizations. Conveniently, it also happens to feature some of the strongest analytics available when the time comes for evaluation. Through the RiSE Facebook page, I receive a weekly report that provides tangible feedback measuring things like page visits, number of likes, and inquiries

Lawler, B. R., Ronau, R. N., & Mohr-Schroeder, M. J. (Eds.). (2016). *Proceedings of the fifth annual Mathematics Teacher Education Partnership conference*. Washington, DC: Association of Public Land-grant Universities.

resulting in engagement with my target audience – all very useful data when determining the extent to which a particular ad or campaign may be generating interest.

Of course, the ultimate benefit of Facebook and social media in general, is the networking factor. Module 6, which focuses on Public Relations, defines this interaction as "a strategic communication process that builds mutually beneficial relationships between organizations and their publics" (Ranta, 2015, p. 72). While defining the groups of individuals or publics you wish to reach is certainly an important step, I realized the power of reaching the mass public, and I learned the importance of honing in on this audience as a strategy to help me determine my target applicant pool.

Facebook and many other social media networks provide free accounts, but paying for certain upgrades or additional or outsourced assistance can be a worthy investment. With careful discretion about available grant funds, we have established contracts with multiple media agencies that have helped to produce professional advertisements for our program, including movie theatre ads, television and radio spots, online banners, and Facebook "boosts" used to generate more content exposure. Module 7 covers each of these options and more, providing helpful tips on production and "Buying a Schedule," while emphasizing the importance of timing. "The most brilliant schedule can be ruined by poor production values and vice versa, a great-looking campaign that no one sees is equally as ineffective" (Ranta, 2015, p. 108). In other words, make investments that count by taking a careful look at the production quality your budget will allow, and be equally critical when negotiating airtime.

While reaching the target audience is the ongoing challenge for any recruiter, I quickly learned just how critical it was to have an established infrastructure in place. Module 8: Website Identity details the basic construction and organization of a site. Within the context of my academic institution, there was already a well-established protocol in place, so most of the technical work had to be outsourced to our campus IT staff. With some teamwork on the content, it didn't take long to launch the main webpage for the RiSE program, and the campus web developers were helpful in offering weekly updates on site traffic through Google Analytics.

But almost immediately after the details of the website fell into place, we had several ad campaigns up and running. The burden of a successful campaign is a lot of traffic, and it didn't take long to realize that I needed another resource for following up on public inquiries and candidate leads. With more assistance from IT, we decided to utilize Google FlowChart, in order to map out a new "landing page," or online destination to be used as an automated tool for directing the influx of interested candidates. Creating this infrastructure was not a simple process, but it had a big payoff.

With interactive buttons and links to Google forms, potential candidates could submit helpful information, and also access needed resources. Riseteachers.org became our easy and catchy URL, for quick reference in radio and TV ads. As a "destination" for general interest, it served to redirect those who are not a good match for the program to more appropriate resources, but in doing so, also helped dedicate more staff time to the most qualified candidates.

In other words, I was no longer working tirelessly running the phones and addressing emails to answer more general questions and redirect misguided inquiries. This multi-purposed informational system and screening tool allowed me to prioritize and focus my efforts on the most viable candidate leads. In following up on these leads, I was able to offer necessary support to individuals needing just a little extra boost to become qualified candidates ready to apply for and begin the program. This combination of infrastructure and outreach is what ultimately translated to success in recruitment.

Evaluating the Campaign

But how could I determine what outreach worked and perhaps more importantly, what might be the best use of future resources? Module 9: Evaluation mentions the importance of measuring effects as a subset of results. It also provides a guideline to evaluate resource use and the effectiveness of a given recruitment strategy.

Google Analytics is a helpful free tool that can assist in calculating traffic data and help zone in on the target audience and what's working in terms of future recruitment cycles. According to Google analytics, our landing page had approximately 7,000 page views and has reached a worldwide audience, which helped prove that our landing page was a success in reaching the public through paid media.

We conducted an 8-month digital marketing campaign with Action News Now (our local media agency), who not only aired a RiSE commercial for us, but also assisted with managing our paid ads through Facebook. This media campaign turned out to be a successful partnership based on our evaluation data through Facebook analytics. We reached over 171,000 people through this social media platform, and based on data submitted by program applicants, we can also confirm Facebook contributed to 10% of our applications. Our Facebook page also generated almost 7,000 clicks and nearly 500 likes, helping build our "brand" and creating future retention towards our program.

Upon conclusion of our first recruitment campaign cycle, I was able to analyze all the data collected and create charts for future campaign investments and decisions. I created a specific chart that represented the RiSE Program leads by recruitment source, with each source category broken down by percentages. The data is based on 334 leads from January 2015 to March 2016, and paid media generated about one third of our leads.

Since the start of recruitment for the RiSE Program in January of 2015, we have had three separate pools of applicants—for a total of 42 applicants. In reference to the previous chart, what this means is that out of those 334 individuals who expressed interest in the program, 42 (or about 13%) submitted applications. So while it helped to see which recruitment methods were effective in generating leads, I wanted to more closely evaluate this critical 13%.

To begin, we examined the percentage of RiSE applications per lead source. I first examined applications sourced from movie ads, finding they were non-existent. This expense did not produce a good return, which is why we will be discontinuing that campaign. Second, while television commercials generated a large amount of leads, the number of applicants from leads generated by our San Francisco Bay Area media campaign were insignificant, with a greater amount of applicants coming from leads generated by our local news agency.

I have found that evaluation is one of the most essential components in analyzing a successful campaign; it can help facilitate discussions, determine what lessons can be learned, and where to focus future efforts. That being said, as a result of our evaluation data, we intend to continue our campaign with our local media agency, Action News, and target more of our audience by expanding to the (more local) Sacramento area. We are working on production with a new media agency to discuss our future marketing campaign and partnership for our second recruitment cycle.

Having the right tools, including the *Implementation Guide* (Ranta, 2015) produced by the MATH Research Action Cluster, and infrastructure in place has not only helped make my recruitment tasks feel more manageable, but also provided a system for tracking my efforts. I look forward to determining the outcomes of future recruitment strategies and ad campaigns in relation to the grant's budget, and more importantly, discovering where improvements can be made as we continue our efforts to recruit future secondary mathematics teachers.

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Comparing Noyce Scholars' Decisions to Teach and Perspectives on Teaching to non-Noyce Scholars

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Scholarships that are designed to combat the teacher shortage problem and increase the number of teachers in high-need fields generally include some financial incentive. The extent to how the financial incentive effects the scholar's decision to become a teacher, or teach in low-income schools, is difficult to measure, but some work has been done to reveal contributing factors. One factor that was found to impact scholars' decisions to accept the funding was the amount awarded. Scholars' were influenced more when the financial incentive covered a higher proportion of their tuition (Darling-Hammond, 2007; Henry, Bastian, & Smith, 2012; Liou & Lawrenz, 2011).

For the Noyce Teaching Scholarship specifically, research has found that many of the Noyce Scholars would have entered the teaching profession regardless of the financial incentive (Bull, Marks, & Salyer, 1994; Liou, Desjardins, & Lawrenz, 2010). However, for those Noyce Scholars who might not have otherwise considered a career in teaching, the financial incentive had a larger impact on their decision to enter the teaching profession (Liou & Lawrenz, 2011).

Competitive scholarships appear to attract individuals with significantly higher academic credentials and higher levels of human capital into teaching, but unless the scholarship programs require recipients to work in high-need schools, they tend to teach in schools and classrooms with more high-achieving and low-poverty students (Henry et al., 2012). The financial incentive offered by the Noyce Scholarship had the most influence on recruiting teachers to high-need schools and toward completing their certification program, but less of an influence on staying in a high-needs school for long periods of time (Liou et al., 2010; Liou, Kirchhoff, & Lawrenz, 2010; Liou & Lawrenz, 2011). Using scholarships as a mechanism to recruit teachers into the education profession and into teaching in high need fields has its own set of challenges. Thus, it is necessary to continue to study these challenges and modify them to meet the needs of the forecasted teacher market.

Though the aforementioned research provides some insight on factors that influence Noyce Scholars' decision to enter the teaching profession and how the financial incentive of the scholarship impacted their decision to teach, little research has been conducted on characteristics unique to Noyce Scholars. Comparing the perceptions of the Noyce Scholars on various aspects of teaching and the teaching profession with a similar group of teachers that did not receive the Noyce scholarship may shed some light on differences between Noyce Scholars and non-Noyce Scholars. The research questions that guided this study were:

1. How do the Noyce Scholars' perceptions of teaching and of the teaching profession differ from the perceptions of a group of non-Noyce Scholars who were certified from the same teacher preparation program?
2. How do Noyce Scholars' decisions about teaching and of the teaching profession differ from the perceptions of a group of non-Noyce Scholars who were certified from the same teacher preparation program?

The work of the Mathematics Teacher Education Partnership (MTE-P) addresses the significant national shortage of well-prepared secondary mathematics teachers. One focus is the recruitment of students into the teaching profession. Data from this study may inform the Marketing for Attracting Teacher Hopefuls (MATH) research action cluster in their work to recruit students into the profession. Identifying how and when groups of students make decisions to become teachers can help when marketing various teacher preparation programs.

Methods and Instrumentation

For this quasi-experimental study, we applied stratified matched sampling to compare the decisions and perceptions of participants who received a Noyce scholarship to those participants who did not receive a Noyce scholarship. Targeted participants were students who received their secondary mathematics or science teaching certification from a university in the southwestern region of the United States sometime from 2002 to 2014. Additionally, all targeted participants were prepared by the same undergraduate teacher preparation program. The data for this study was generated from one survey, administered electronically, to the 61 participants (29 Noyce Scholars and 32 non-Noyce Scholars) in the summer of 2015.

This survey was adapted from two other surveys; the Schools and Staffing Survey (SASS) created by the National Center for Educational Statistics (NCES, 2012) and the Noyce Scholar Survey developed at the University of Minnesota for the Noyce Evaluation Report (University of Minnesota, 2012). The resulting survey contained 70 questions that were classified into nine sections: Personal Information (PI), Employment Information (EI), Decisions on Becoming a STEM Teacher (DBST), Mentoring and Induction Experiences (MIE), Impressions of Teaching and Current Job (ITCJ), Plans for Graduate Education (PGE), Teacher Preparation (TP), School Climate and Teacher Attitudes (SCTA), and the Noyce Scholarship (NS).

The questions on the survey had a variety of answer types. Some questions used categorical scales, some were ordinal scales, and others were open-ended. Most of the ordinal scale questions had multi-part statements where participants ranked the statements on four- or five- point Likert scales. The full set of questions used for the survey can be found at aggieteach.tamu.edu/noyce-monitoring-and-evaluation-project.

Results

Responses from the survey were analyzed to determine any statistically significant differences between two independent groups of participants, Noyce Scholars and non-Noyce Scholars, across four categories of the survey. The four categories are: Decisions on Becoming a STEM Teacher (DBST), Plans for Graduate Education (PGE), Teacher Preparation (TP), and School Climate and Teacher Attitudes (SCTA). Some questions within categories were analyzed on a statement-by-statement basis and for others latent variables were created via an Exploratory Factor Analysis. For the latent variables, corresponding factor scores were calculated and Mann-Whitney *U* tests were used to determine any significant differences between the groups on both the latent variables and the statement-by-statement analysis. The two categories that produced statistically significant differences between groups were DBST and PGE. No statistically significant differences between Noyce Scholars and non-Noyce Scholars were found for the TP and SCTA categories.

Decisions on becoming a STEM teacher. The DBST category contained two nominal scale questions. The first question was “Did any of the following help you decide to become a STEM teacher?” A list of nine statements followed this question and participants responded to each statement with “yes” or “no.” Responses to two of these statements were statistically significant. The first of these two was, “I like the flexibility and/or autonomy of STEM teaching.” Results of the Mann-Whitney *U* test ($p = 0.011$) indicated that non-Noyce participants were influenced more by the flexibility and/or autonomy of STEM teaching than the Noyce participants. Glass’ effect size value ($\Delta = 0.863$) suggested a high practical significance.

The second statement that produced a statistically significant difference was “I feel that a teaching career is/will be conducive to my family life.”. Results of the Mann-Whitney *U* test ($p = 0.005$) indicated that non-Noyce participants were influenced more by a teaching career being conducive to family life ($M = 0.88$, $SD = 0.336$) than Noyce participants ($M = 0.55$, $SD = 0.506$). Glass’ effect size value ($\Delta = 0.982$) suggested a high practical significance.

The second question in the DBST category that produced a statistically significant difference ($p = 0.033$) between non-Noyce ($M = 1.69$, $SD = 0.471$) and Noyce participants ($M = 1.41$, $SD = 0.501$) was “At what point in your life did you decide to become a STEM teacher?” The frequency counts indicate that significantly more Noyce participants decided to become a STEM teacher before the age of 18 ($n = 17$) than non-Noyce ($n = 12$). Additionally, significantly more non-Noyce participants decided to become a STEM teacher between the ages of 19 and

22 (n = 22) than Noyce (n =10). Glass' effect size value (Δ = 0.594) suggests a moderate practical significance.

Plans for graduate education (PGE). The PGE category contained two nominal scale questions. The first question was "Since graduating from the university have you taken any graduate level classes?" Participants responded with "yes" or "no." The Mann-Whitney *U* test produced statistically significant difference (p = 0.042) between the two groups. These results indicate that Noyce participants had taken significantly more graduate level classes since graduating from the university than non-Noyce participants. Glass' effect size value (Δ = 0.564) suggests a moderate practical significance.

The second question regarding plans for post-baccalaureate education was "Since graduating from the university have you received any advanced degrees?" and participants responded "yes" or "no." A Mann-Whitney *U* test indicated that there was a statistically significant difference (p = 0.036) between the two groups. These results indicate that significantly more Noyce participants had obtained a master's degree than non-Noyce participants. Glass' effect size value (Δ = 0.647) suggests a moderate practical significance.

What was Learned from this Work

The Noyce Scholars, in general, made decisions about their future plans at younger ages and for different reasons than the non-Noyce Scholars. Significantly more Noyce Scholars decided to become teachers before the age of 18 than non-Noyce Scholars. Furthermore, external factors like flexibility or autonomy of STEM teaching and conduciveness to family life seemed to be less of an influence on Noyce Scholars' decisions to teach. This may suggest that Noyce Scholars were more actively thinking about their future careers while still in high school. Additionally, Noyce Scholars may decide to become teachers for reasons other than "flexibility or autonomy of STEM teaching" and "conduciveness to family life" for deciding to be a teacher. Noyce Scholars appear to be less influenced during their college-aged years on making a career choice since many of them made the decision before 18. Non-Noyce Scholars, on the other hand, seem to be enter college less decided on a career choice and may be more influenced by external factors when choosing a career. Thus, when recruiting teachers into the profession during the college years, external factors like "flexibility or autonomy of STEM teaching" and "conduciveness to family life" may be good aspects of the teaching profession to highlight to recruit college aged students into the teaching profession or at least to get them thinking about selecting teaching as a career.

Results in the PGE category also indicate that Noyce Scholars decide to invest in their graduate education at a higher rate than their non-Noyce counterparts. This could be due, in part, to the high academic achievement that Noyce Scholars had to demonstrate as an undergraduate to receive the Noyce funding. Noyce scholars may value education, in general, more than the non-Noyce students. Additionally, receiving the scholarship funds as an undergraduate could have put the Noyce Scholars in a position where they had less student loan debt and thus, more willingness to invest money in graduate studies. This notion cannot be fully supported by the results of this study, but it is something that could be explored in future studies.

Conclusion

One of the reasons MTE-P was formed was to "address the significant national shortage of well-prepared secondary mathematics teachers who can support their students in achieving the Common Core State Standards for Mathematics" (Association of Public and Land-Grant Universities, ND). The Noyce Scholars are a group of well-prepared secondary mathematics teachers. Discovering any unique characteristics about the Noyce Scholars may give some insight to how better recruit high-achieving students into the teaching profession. This study provides some examples of such insight.

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Closing Remarks

From Improvement to Transformation

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The event of the Fifth Annual Mathematics Teacher Education Partnership (MTE-P) conference is a reasonable time to reflect upon MTE-P efforts to transform secondary mathematics teacher preparation programs in the United States, assess current initiatives, and determine potential actions that can and should be attempted in the near future. MTE-P has steadily moved from forming action plans and partnerships, to testing interventions, to implementing transformational efforts involving multiple institutions in multiple states. This year's conference focused on learning how to make MTE-P work transformative by using the innovations developed by multiple RACs at multiple sites to leverage meaningful change in both local partnership programs, and in the larger system of secondary mathematics teacher preparation.

Guiding Principles

One of MTE-P's initial efforts was to create a set Guiding Principles (revised: MTE-P, 2014) that described and established a shared vision for secondary mathematics teacher preparation, a vision necessary for the overall continuity and direction of our local and networked efforts. Moreover, this vision was expected to be a living document, to be explored and refined by MTE-P members as well as others involved in preparing secondary mathematics teachers by:

1. building a national consensus on what effective secondary mathematics teacher preparation programs need to do in order to develop teacher candidates who promote mathematical excellence in their future students;
2. enhancing communication among the partners involved in a secondary mathematics teacher preparation program in order to clarify program goals, to assess the effectiveness of the program, and to guide program development and revision;
3. serving as the framework for an emerging national research and development agenda related to secondary teacher mathematics preparation; and

[1] Ronau contributed to this paper while serving at the National Science Foundation. The comments expressed here are those of the author and do not necessarily reflect the views of the National Science Foundation.

4. helping to organize the identification, development, and dissemination of resources supporting effective secondary mathematics teacher preparation programs.

At present, MTE-P has ten Guiding Principles that must be considered in the effort to address the identified problem, the reform of secondary mathematics teacher preparation programs. The Guiding Principles are organized into three sections: Partnerships; Teacher Candidate Knowledge, Skills, and Dispositions; and Program Structures. Each of these areas are critical influences on programs; however, their interactions may be even more important. The manner in which these Guiding Principles interact is evidenced in MTE-P's primary driver diagram, a representation of the working theory of practice improvement. This driver diagram, Figure 1, serves to create a common language among the community and directs the efforts to solve this shared problem.

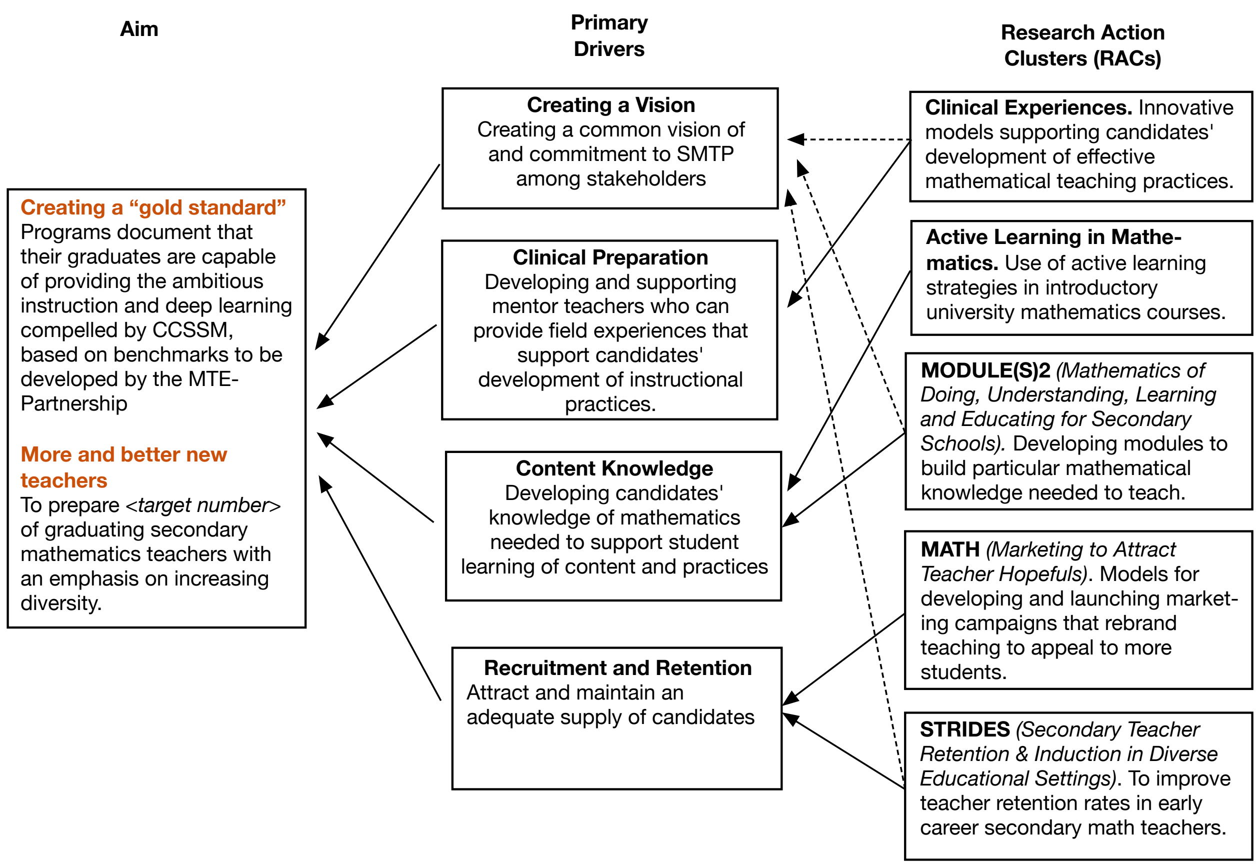

Figure 1. The driver diagram of the MTE-Partnership.

Vision

These principles led to the development of two aims: (1) Create a "gold standard" in which programs document that their graduates are capable of providing the ambitious instruction and deep learning compelled by Common Core State Standards for Mathematics and other college and career-ready standards, based on benchmarks to be developed by MTE-

P; and (2) produce more and better teachers, specifically increasing the quantity of well-prepared candidates by 40% by the year 2020. To achieve those aims, four primary drivers were identified: creating a vision, clinical preparation, content knowledge, and recruitment and retention. Research Action Clusters (RACs) formed to begin to study the issues raised in the Guiding Principles, with the aims in mind for the work.

From tweaking to transformation

That history of work in the MTE-Partnership has created a fervent of tinkering, studying, revising, and re-implementing as members of the RACs carry out Plan-Do-Study-Act (PDSA) cycles. Which brings us to the present opportunity to refocus on the charge of the MTE-Partnership, to transform secondary mathematics teacher preparation programs in the United States. This conference launches the project into a fifth year of work on this transformation. The gathering served as an opportunity to step back and share out what the community is learning as it tinkers, tweaks, and studies its efforts. But also the community was redirected to consider the theory underlying and measures that indicate success with the transformation of secondary mathematics teacher preparation (consider Figure 2). Having looked back, we hope to examine the activity of this fifth conference and consider what may be next steps for the MTE-Partnership.

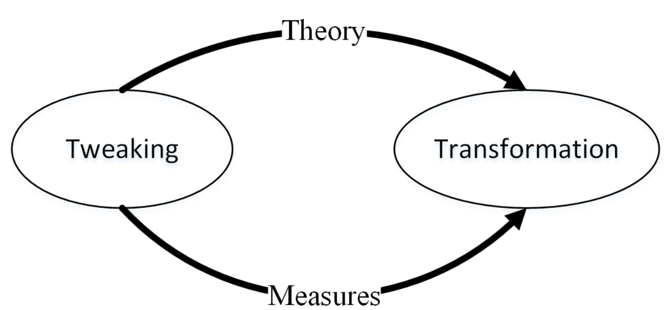

Figure 2. A model to support consistent, continuous classroom change.

The MTE-Partnership today

One strength of the MTE-Partnership is the number of local teams that form the overall partnership; it is a networked improvement community (NIC). This network permits efforts in multiple areas to be shared and replicated in a collaborative, controlled, cyclic process that offers both breadth and depth—a foundational element of improvement science (Bryk et al., 2015).

Networked Improvement Communities and Improvement Science

The MTE-Partnership follows the principles of improvement science to accelerate how the field of mathematics education learns to improve. The core principles of improvement science are: make the work problem-specific and user-centered; variation in performance is the core problem to address; see the system that produces the current outcomes; we cannot improve at scale what we cannot measure; anchor practice improvement in disciplined inquiry; and accelerate improvements through networked communities.

MTE-P is organized as networked improvement community in alignment with improvement science, and is a key construct for involving practitioners in both the implementation and the research of the innovation targeted by the vision and action plans. NICs offer channels of communication that provide built-in opportunities to leverage local repeated studies of disciplined inquiry (e.g., Plan-Do-Study-Act Cycles) into state-wide or nation-wide impact. Scaling up the innovation is the next automatic step as additional partnerships decide to test the innovation for themselves and share the results.

Partnerships

The MTE-Partnership project is a relationship-focused enterprise, in which several types are partnerships are prevalent. The formation of local teams, consisting of at least one university with a secondary mathematics teacher preparation program, one school district, and one additional member (open educational category). MTE-P benefits in two ways from this structure: (1) partnerships between university programs and K-12 schools contains the most important stakeholders in the process of secondary mathematics teacher preparation, and (2) having an open category for local partners resulted in a wide range of stakeholders in the overall MTE-P membership. These two benefits are both well-aligned to the first NIC principle, making the work problem-specific and user-centered.

A second type of partnership is carried out among individuals who participate in Research Action Clusters (RACs). Five active RACs are working to address various components of the Guiding Principles. Collectively these efforts have the potential to form a clear and compelling set of pathways for teaching and teacher preparation that will be shared by many institutions and states.

For example, twelve partner institutions are involved in the Active Learning Mathematics (ALM) RAC, bringing different local contexts to the effort. ALM aims to improve student success in undergraduate mathematics courses, especially Pre-calculus through Calculus 2, by changing the way undergraduate mathematics is taught, shifting from a passive to an active role for the learner. This set of partner institutions share a common vision of transforming undergraduate mathematics teaching and learning through the use of active learning, although each local team may approach the problem differently. Common measures, used to document each program's progress, offer meaningful comparisons of efforts among the different programs and allow the MTE-Partnership to judge collective impact.

The Marketing to Attract Teacher Hopefuls (MATH) RAC has also responded to the Guiding Principles, and specifically the recruitment challenge in the primary drivers. MATH developed a Secondary Mathematics Teacher Recruitment Campaign Guide www.surveymonkey.com/r/MATHImplGuide, which is now being implemented and evaluated by 14 different local teams. The results and products of PDSA cycles conducted over the past two years by teams within this RAC are documented at padlet.com/ed_dickey/vhle4gisbq82.

Each of the three other RACS, Clinical Experiences, MODULE(S)^2, and STRIDES are examining other elements of the programmatic effort to prepare and retain more secondary mathematics teachers. The RAC structure is the driving force for the MTE-Partnership, each formed by and representing multiple partnerships. This structure creates working teams small enough to be efficient in planning and implementing innovations but with built-in connections to make scaling-up those initiatives seamless and informative. Each RAC is a NIC in and of themselves and collectively they form a larger nation-wide NIC.

State of affairs

Improvement science is a user- and problem-centered approached to improving education, explicitly designed to accelerate learning-by-doing. At present, much productive work has been accomplished in the “learning-by-doing” spirit amid the vast MTE-Partnership. It has proven to be an organization capable of learning and improving, embracing change and valuing the previously invisible problems as they emerge.

Looking forward

The editors of the conference proceedings had the opportunity to closely review the numerous activities reported out at the conference, be challenged by the presentations of the plenary sessions, and examine the new ideas generated by the RACs while there wish to close with thoughts about and challenges regarding the future direction of the MTE-Partnership.

Guiding Principles

In revisiting the Guiding Principles, driver diagram, and work of the RACs, we were intrigued to notice the MTE-Partnership currently has RACs that respond strongly to 61% (20 of 33) of the Indicators of the ten Guiding Principles. We recognize this limited focus was necessary and intentional from the beginning of the project as participants recognized the complexity of the task and realized not everything could be done at once. Working groups set priorities for their areas based on what they thought could be addressed had the most potential to leverage change. RACs were formed from these discussions which helped focus the work and achieve completed products over the first few years.

There are several Indicators of the Guiding Principles that have not been strongly or explicitly addressed by the current RACS, listed in Table 1. For example, the notion of shared engagement and responsibility (1C) can be found in found in elements of the work of some RACs. The Clinical Experiences RAC relies on strong partnerships between schools and colleges of education, collectively designing and sharing responsibility for success. However, not all constituents are actively engaged to the degree found in Guiding Principles. To date, this level of commitment of the site-level partners across all RACs remains a challenge. This challenge is closely tied to Guiding Principle 2 and its Indicators.

Table 1.
Specific Indicators of the MTE-P Guiding Principles not currently addressed by RACs.

#	Guiding Principle and Indicators
1.	*Partnerships as the Foundation*
	1.C. Shared Engagement and Responsibility
2.	*Commitments by Institutions of Higher Education*
	2.A. Institutional Focus
	2.D. Institutional Support for Faculty
4.	*Candidates' Knowledge and Use of Mathematics*
	4.D. Nature of Mathematics
5.	*Candidates' Knowledge and Use of Educational Practices*
	5.A. Design of Instruction
	5.B. Instructional Methods
	5.C. Assessment and Reflection
	5.D. Use of Instructional Technology
	5.E. Attention to Diversity
6.	*Professionalism, Advocacy, and Leadership*
	6.A. Integrity
	6.B. Intellectual Spirit
	6.C. Sense of Justice
	6.D. Stewardship and Leadership

Guiding Principles 4 and 5 allude to content and pedagogical content knowledge. The Active Learning Mathematics and MODULE(S^2) RACs are intentional about creating a more robust understanding of the content of the discipline, mathematical habits of mind, and the specialized knowledge of Mathematics necessary for teaching. However, there is no specific effort to ensure "teacher candidates understand, and are able to convey to their students that mathematics is a living and evolving human endeavor that relies on logic and creativity, and it is valuable for citizenship, for the workplace, as well as for its intrinsic interest" (MTE-P, 2014, p. 4). The focus on student's learning educational practices, especially those specific to secondary mathematics instruction is not yet addressed by the MTE-Partnership. We do recognize a fundamental element of the Clinical Practices RAC is to provide preservice teachers opportunities to practice and receive feedback on educational practices, which greatly contributes to learning. On the other hand, the Clinical Practices RAC addresses a small, but essential, part of mathematics teacher education programs.

An attention to the development of a sense of social justice, including equitable pedagogy and attention to diversity, has not yet received the direct and concentrated attention these challenges call for—this is evidenced by the strong interest and requests that emerged from the diversity and equity session of the conference. More broadly, the partnership does not yet have a research cluster that attends to the development of professionalism, advocacy, and leadership. As STRIDES begins to mature, we suspect they are likely to take up some of the issues identified in the Indicators.

Taking stock of where MTE-P is successful and where there remains goals yet to be addressed should help define next priorities of the partnership. Does MTE-P have an explicit, commonly understood plan of when and how and when MTE-P will address additional indicators of the Guiding Principles? Are some of these indicators critical for RACs and/or local team effectiveness? What supports do local teams need to address this set of indicators? How can the MTE-Partnership answer these questions and monitor its progress on addressing the Guiding Principles?

As evidenced by the conference goals, several indicators that have yet to receive explicit, focused attention point toward issues of equity, social justice, and advocacy as well as the challenges of institutional change, an underlying element of program reform. These are long-term targets for change. We are hopeful the work of the MTE-P RACs as shared in this set of proceedings may set the stage so efforts can be launched to successfully address those targets in the near future.

Equity, Social Justice, and Advocacy

MTE-Partnership members recognized that although a number of the RACs included issues of equity and social justice in their planning, the resultant activities and strategies that might impact this construct have been less than clear. As such, one goal for the Fifth Annual MTE-Partnership Conference was to, “make equity and social justice more explicit as an essential component of the partnership aim.” Part of the time set aside for work at this conference was dedicated to addressing *equity and social justice* and the advocacy for it. At the beginning of the conference a work session on Equity and Social Justice was held and open to all participants; the results of this work session can be found in these proceedings. Additionally, the RACs were asked to explicitly address equity and social justice in their individual working sessions. At the end of the conference each RAC included in their reports the results of their focused conversations and connections to Equity and Social Justice. If the Guiding Principles are to continue to direct the work, it seems the challenges and questions that emerged in both the work session and RAC meetings must be followed upon.

Transformation

Review of the Guiding Principles made evident that numerous elements of the MTE-Partnership charge point directly to the complexity of program transformation. Several elements of transformation are flourishing at present. RACs are engaged in efforts to expand their work to additional partnerships through Plan-Do-Study-Act cycles, testing and evaluating the products and materials that have been developed. As they continue to refine their innovations and scale-up their influence the larger MTE-Partnership Network Improvement Community is poised to support and connect their work. For example, the MTE-P Hub helps to showcase the work of the RACs, provides funding to help with face-to-face RAC meetings, serves as a repository for RAC materials, and hosts and supports events such as this conference.

Yet sustainability of the RACs must continue to receive priority; pursuit of funding in support of the work is one element of the challenge. Much of the efforts of RAC members are volunteer and can cause stress and undue pressure over time. Many have submitted grant proposals and some have received funding. But the question still looms as to how the RACs can be transformed into more sustainable networks? How can the MTE-Partnership help universities, especially the administrators under which the MTE-P faculty serve, understand the impact improvement science has made on their campuses?

How can MTE-Partnership make the work of the RACs more visible and desirable? Much of this has been left up to the individual partnerships, but there may be a key role for the RACs and the MTE-Partnership Hub. How are RACs perceived at the local sites? How can the Hub help with visibility, persuasion, in implementation, and evaluation at the local levels? Various forms of presentations do share Plan-Do-Study-Act cycles, but the details how of the Networked Improvement Communities fold into the process are scarce. Suzanne Wilson's model of tweaking our way to transformation through theory and meaningful measures (Figure 2) seems to fit the MTE-P process well. But it leaves us with the challenge to learn how program transformation can take place. The fifth conference concluded with an emerging working group on Program Transformation—clearly a next needed consideration.

Improvement science continues to be a perfect match to this challenge. It allows the MTE-Partnership to engage in an iterative process over considerable periods of time. Further, the goal of program transformation is not about a final state, but to welcome and engage in continuous improvement. The overall goal is to develop the necessary knowledge-base and action steps for the reform of secondary mathematics teacher preparation to spread effectively within and beyond the MTE-Partnership.

Summary

MTE-P has come a long way in five years. Starting with vague hazy ideas about changing teacher education, MTE-P has managed to develop common vision across hundreds of individuals representing 30 states. With RACs as a driving force, this project has evolved from inspiration to innovation to action. Although MTE-P can point to many significant and important accomplishments over five years, the work is just beginning. Changing secondary mathematics teacher programs seems to be a herculean task that has resisted past efforts of significant change. On the other hand, MTE-P is a special group, in terms of size, scope, and dedication, that has a chance to make a much-needed difference.

At this point in its evolution, MTE-P has four mature RACs (MATH, ALM, CERAC, and MODULE(S^2), with STRIDES in a nascent state), that have created products that can be used by any of the partnerships. Wilson (2011) identified a "downward cycle" in considering the challenges to effective mathematics teacher preparation (modified by Martin & Strutchens, Figure 3). The RACs of the MTE-Partnership may be beginning to reverse this downward trend. At this phase of development MTE-P has evolved to begin to determine which combination of these innovations are capable of helping any partnership team contribute to MTE-P's twin aims, to create a "gold standard" for secondary mathematics teacher preparation, and to produce more and better teachers. Perhaps materials from all the RACs must be implemented with a high degree of fidelity to achieve a measurable effect on these two aims. On the other hand, the requirements for making a difference could be less stringent. The current move from innovation to transformation sets the stage to answer questions of this nature.

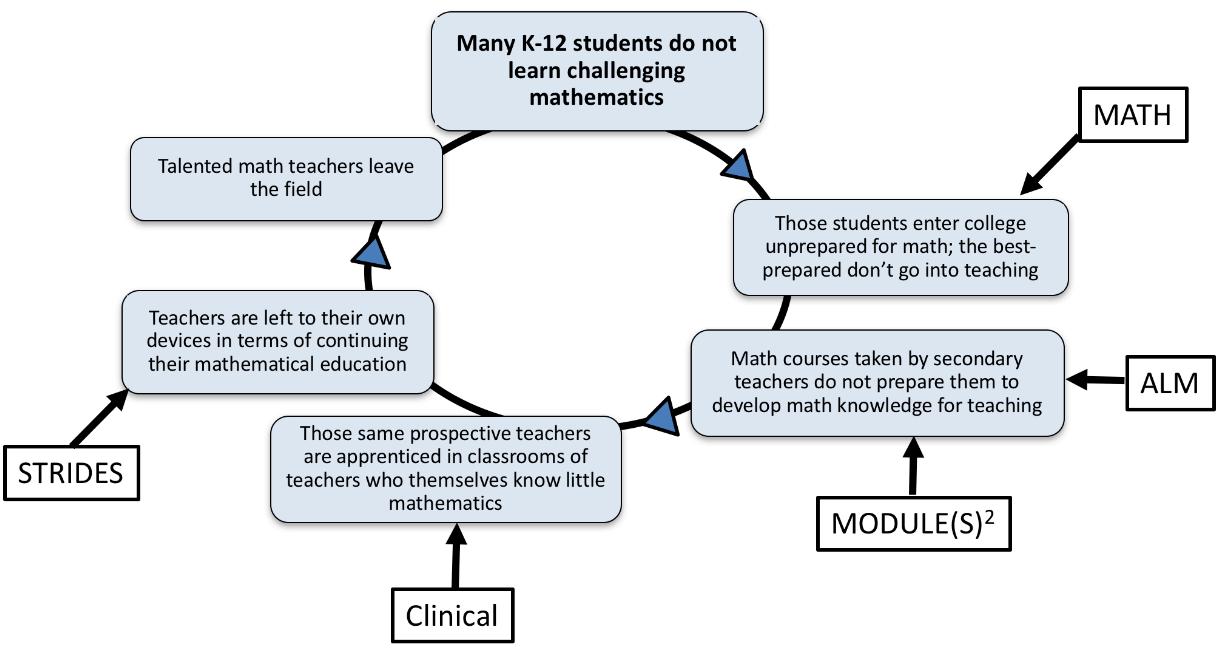

Figure 3: Reversing the "downward cycle in mathematics teacher preparation" (Martin & Strutchens, in press).

The MTE-Partnership Networked Improvement Community provides a structure in which individual efforts of transforming local mathematics teacher preparation through integrating multiple sets of RAC materials into their programs contribute to a nationwide study that has the potential power to provide answers to questions about complex issues. As the community makes progress toward its aims through rapid tests of change, it also learns much about the detail and complexity of the problem. Our efforts for improvement are grounded in a purposeful fraternity of expertise, creating, sharing, and building on the hard work of one another. The MTE-Partnership has placed us in a unique position that offers the opportunity to create evidence that justifies meaningful change.

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