Supporting Beginning Mathematics Teachers with Technology-based Professional Development

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INTRODUCTION

The relationship between Professional Development and Support Models on the Work and Retention of Secondary Mathematics Teachers merits careful examination. National reports identify the need to increase the pool of highly qualified mathematics teachers to improve mathematics education and maintain the United States' economic competitiveness (National Academy of Sciences, 2007; Glenn Commission, 2000). Beyond the recruitment of mathematically knowledgeable teachers, the issue encompasses teacher support, professional development, and retention. Research reveals that many new recruits leave their school and teaching a short time after they enter (Ingersoll & Smith, 2003; Boyd et. al., 2009). Teachers who leave first are often those with the highest qualifications. While the most effective teachers transfer to higher achieving schools, less effective teachers stay in lower-performing schools (Boyd et. al., 2005).

Attrition of new teachers is often related to "working conditions" and lack of support (Ingersoll, 2001; Smith & Ingersoll, 2004; Johnson et al., 2004), though pay also plays a role (Hanushek, Kain, & Rivkin, 2001). Support includes professional and collegial support: working collaboratively with colleagues, coherent, job-embedded assistance, professional development, having input on key issues, and progressively expanding influence and increasing opportunities (Johnson, 2006). Preparation, support, and working conditions are essential to teachers' effectiveness and realizing the rewards that attract and keep many in teaching, despite the low pay (Johnson & Birkeland, 2003; Liu, Johnson, & Peske, 2004; Johnson 2009). A status report focusing on the professional development and support of teachers (Darling-Hammond et al, 2009) summarized findings and offered recommendations for effective professional development, concluding that "well designed" professional development can influence teacher practice and student performance.

Ingersoll and May's recent analysis of Mathematics and Science teacher turnover in the past two decades indicates a steady increase in the rate of the turnover. Since the pipeline of new mathematics and science teachers is more limited than in non-STEM disciplines, individual schools are under much stress to consistently replace those that leave. This is so even though the number of newly qualified teachers produced each year should strictly speaking be enough to cover retirements and increases in student enrollments. Indeed, upon leaving their teaching positions, mathematics and science teachers are more likely move into non-educational professions than teachers in other fields. According to data gathered by the National Center for Education Statistics with the School and Staffing Survey and the Teacher Follow-up Survey, the provision of useful Professional Development is one of the organizational factors influencing choices of mathematics teachers to leave or remain in their positions. Another factor is the degree of individual classroom autonomy (Ingersoll & May, 2010). Support must be specific in addressing the needs of teachers in their particular contexts (Fulton et al., 2005).

To focus attention on the retention and the impact of support and professional development on mathematics teacher retention, both those who move and those who leave teaching altogether, a study was developed in the fall of 2006 by the California Mathematics Project. This study is entitled California Mathematics Project Supporting Teachers to Increase Retention (CMP STIR) and was funded by the California Postsecondary Education Commission under the Improving Teacher Quality grant program to address both dimensions of teacher retention across California. The project focuses on secondary teachers in their first five years of teaching primarily mathematics who work at schools and/or districts eligible under the No Child Left Behind guidelines or in hard-to-staff schools.

A major component of the project is research that would extend and deepen the knowledge base on mathematics teacher retention. Since the base for this study of support and sustainability of mathematics teachers involves 10 CMP regional sites, its design is complex, diverse, and builds on a professional development network built up over 25 years, thus embracing a diversity of perspectives on the retention of mathematics teachers through support and professional development.

In this paper, models, activities, and research results are shared from four regional sites of the CMP STIR project, where support for teachers in their first five years of teaching includes the use of integrated technology in the process of teaching and learning mathematics to varying extents. Differences in the realization of the professional development provide multifaceted insights on the acquisition of Technological Pedagogical Content Knowledge (Mishra & Koehler, 2006) as we describe the unique features of each site and relate these differences in participant profiles and longitudinal site results. Motivating this analysis is the belief shared by all four site directors that technology can play an important role in re-engaging students and providing learners a chance to explore, create and establish meaningful connections between mathematical concepts and contextual paradigms. NCTM's position in *The Role of Technology in the Teaching and Learning of Mathematics* (NCTM, 2008) encourages incorporating "instructional technology in learning outcomes, lesson plans, and assessments of students' progress" (p. 1), and underlines the role of mathematics teachers as guides for providing students with the proper tools to "support and extend mathematical reasoning and sense making, gain access to mathematical content and problem-solving contexts, and enhance computational fluency" (p. 1).

Nowadays, technology is widely used by research mathematicians for modeling or as an exploratory tool, at times advancing the field through production of knowledge that would not have been accessible otherwise. On the other hand, reasons for a slow advance in the use of technology in the mathematics classroom include widespread shortsighted beliefs about what mathematics is and how it should be taught. Technology is now widely available to classroom teachers, however learning how to use it effectively still requires a time commitment that many beginning teachers may not be inclined to invest, thus making it challenging to learn how to teach with technology and how to support student learning of mathematical concepts through the use of technology. Zbiek and Hollebrand (2008) document teachers' challenges with the incorporation of technology in the classroom as a lack of confidence or competence with the technology, and discomfort with the mathematical connections established through a technological approach to teaching. The mathematical and pedagogical sophistication necessary to fully integrate technology within a mathematics teaching and learning environment need to be further examined.

Support of beginning teachers with technology can take several forms: from learning to operate presentation tools such as active or smart boards; to using technology as an organizational support tool such as spreadsheets for grade reporting; to adopting alternative types of communication tools such as websites or online communities; and to higher levels of integration of technology specific to the content taught. Examples of the latter in mathematics include dynamic geometry software such as The Geometers' Sketchpad, or handheld computing and graphing devices such as those provided through TI-technologies. When learning to teach mathematics with technology in a manner that emphasizes mathematical reasoning and sense-making in the classroom, a focus on Content Knowledge is necessary to ensure that ultimately teachers will embrace the type of mathematical practices described in the Common Core documents as being able to design challenging tasks that promote students' mathematical habits of mind. The difficulty encountered by many beginning teachers grappling with the intricacies of the teacher-learner-content didactical triangle is to become comfortable enough with the tools that they can be smoothly integrated into and supportive of all sides of the triangle.

We focus on the impact of technology-based professional development on beginning teachers' sense of empowerment, both in the classroom and in the broader mathematics education community. As we completed our third year of data collection, the importance of technology emerged as a recurring theme among several sites, an exciting result in light of the fact that California ranked 49th in *The 2008 State New Economy Index* (The Information Technology & Innovation Foundation, 2008, p. 13). Some sites have identified technology as a focus of their content-related professional development in order to improve teachers' confidence, in line with Darling-Hammond's findings about teachers' priorities for professional development opportunities (Darling-Hammond et al, 2009), while others found technology permeating their support model even though it may not have been an initial focus.

RESEARCH DESIGN AND METHODOLOGY

The project is multifaceted in both the range of professional development models and the research design. In general, CMP STIR is a 5 year intervention project with the first three years focused on systematic and sustained support, year 4 transitions to leadership development, career advancement and school and district support, and year 5 emphasizes collaboration, communication, and dissemination. Although specific dimensions of the professional development vary from site to site, the general model for the first three years was (1) intensive professional development and (2) systematic and sustained academic year support. The intensive PD consisted of Institutes and follow-up, content, and communities of practice, while the support may have included coaching, lesson study groups, school site networking, data driven reflection, access to resources, district and/or school support. To study the major question of teacher retention, the project design consists of both quantitative and qualitative data. Overall, the research design encompasses project level longitudinal data, site level data, and case studies in three of the sites. The site level data involves baseline data providing a history of attrition for each site across a five-year period from 2002 - 2006, teacher content knowledge, student achievement data, site yearly reports, teachers' monthly logs, focus group interviews, administrator interviews, and exit interviews.

Across all sites, six electronic logs were collected throughout each the academic year. The first log addressed teaching goals. In another log, teachers looked at opportunities and challenges experienced in their teaching. Each year teachers also shared their favorite lesson taught. Results from participants' responses were analyzed both quantitatively and qualitatively to reflect the impact of the professional development received at respective sites. A numerical comparison of percentages of responses that address technology helps to identify the success of technology-embedded support within and across sites. A qualitative analysis of teachers' responses using the Mathematics TPACK Framework (AMTE, 2008) supports a more in-depth examination of areas of growth and remaining challenges for teachers in relation to the use of technology as they move through various stages of TPACK development (Niess et. Al., 2009).

Site Model Overview

University of California Los Angeles Mathematics Project (UCLAMP)

UCLAMP partnered with Texas Instruments (TI), a technology corporation that manufactures graphing calculators, to train the participants in the use of the TI-Nspire graphing calculator. The participants attended a one-week institute in June 2008. Three days of the institute were dedicated to the TI-Nspire training and two days focused on the topic of functions. A UCLA mathematics department member presented on functions one of the days of the institute.

In addition to the one-week institute, the participants attended nine Saturday follow-up sessions and a three-day retreat. The focus of the follow-ups alternated between TI-Nspire training, mathematics content, and pedagogical issues. At the retreat, participants engaged in mathematics games, attended a mini-conference put on by other UCLAMP teacher leaders, and were involved in a mathematics lesson presented by a UCLA mathematics department member. UCLAMP was able to use grant funds to purchase twenty TI-Nspire calculators for each school participating in the grant.

During the second year of the grant UCLAMP used grant funds to hire a coach. The coach visited teachers in their classrooms to help them plan and implement the TI-Nspire lessons and activities they received during the professional development. The coach also taught model lessons in classrooms and co-taught lessons with teachers.

This model of professional development was chosen because UCLAMP believes that technology should be incorporated into mathematics instruction. The TI-NSpire hand-held technology is a tool that can make mathematics more accessible to students. The TI-NSpire training that the teachers received was an opportunity to increase their content knowledge and provide them with another pedagogical tool to make mathematics meaningful for their students.

California State University, Bakersfield (CSUB)

California State University Bakersfield's choice of support model draws both from the program coordinators' knowledge of the district's needs, and from the nature of pre-existing programs in the region such as the Beginning Teachers Support and Assessment (BTSA) program, or the Leadership Retreat organized in collaboration with SJVMP. Kern County recruits heavily from the upper Midwest. These teachers generally obtain their teaching credential along with their baccalaureate degree, whereas in California, the credential generally requires an additional year of post-baccalaureate courses. Thus, many teachers obtaining their credential outside of California fall behind in graduate credits and end up at the bottom of the pay scale. Historically, these teachers would earn a graduate degree in Counseling or Administration and leave the math classroom. The baseline data collected showed an average teacher attrition rate of 18.5% per year. The project aims to increase mathematics teacher retention by deepening teachers' mathematics content understanding through coursework in CSUB's Master's of Arts in Teaching Mathematics (MATM), extending pedagogical content knowledge through two intensive professional development institutes and follow-up meetings that include discussion of, and strategies for, classroom instruction and management, and increasing their leadership roles on their own campuses. During year three and year four, the retention cohort was invited to participate in the Joint Leadership Development Institute at Three Rivers, hosted by the San Joaquin Valley Mathematics Project and Cal Poly SLO/CSU Bakersfield Mathematics.

Through this support model, teachers are provided with the opportunity to take one course per quarter in the MATM. The Department of Mathematics being very collegial, this model not only impacts subject matter content knowledge, but also allows for effective collaborations among participants while working together on course work, or sharing teaching ideas and other concerns with one another and the faculty in an atmosphere of nurtured community. The heavy technology focus of most courses such as Dynamic Geometry, Discrete Mathematical Models, or Numerical Approach to Calculus, engages teachers in first-hand experiences with educational technologies they are then able to transfer to their own classroom. The collegial, technology intensive and constructivist nature of the MATM meets some of the immediate needs of these individuals by breaking their classroom isolation while providing the tools to implement new teaching strategies with their students. Early in the data collection, one teacher shared with us *"I already know what the unsuccessful lesson feels like. I hope to learn the successful strategies that will make my lessons work!"*

In addition to this intensive course work, participants at CSUB had the option to attend yearly summer institutes aimed at addressing specific pedagogical content knowledge needs and expanding on Technological Pedagogical Content Knowledge. These needs are self-identified during the school year to promote a model of professional development that is not only Content Knowledge and Community centered, but also focused on Teacher, and Assessment and in-line with the recommendation from the "How people learn" framework (Bransford & Brown, 2003).

In summer 2007, 20 participants attended a "Meaningful Algebra" one-week intensive workshop that addressed the key California algebra standards, developing activities adaptable to any algebra book, modeling instructional strategies that teachers can use in their classrooms, and providing research-based information about learning. In summer 2008, 6 participants attended a Proportional Reasoning workshop where integrated-type curriculum as well as other research-related publications supported the teachers' inquiries and discussions. Other support and engagement activities for participants include attending additional technology-based workshops and conferences, engaging in leadership positions at their school, self-reflecting on teaching practices through action research projects, and presenting at regional conferences. Throughout the initial three-year project, opportunities for attending TI-Nspire workshops were provided, as well as participation in a T^3 Regional Institute in the fall 2010.

By the end of spring 2010, the following courses had been successfully completed by CSUB CMP-STIR participants:

Summer	Fall	Winter	Spring
➢ Math 525: Dynamic Geometry (18) - *Geometer's*	➢ Math 520: Discrete Mathematics Modeling (18) -	➢ Math 526: History of Mathematics (16) -	➢ Math 523: Geometric Linear Algebra (15) - *TI*

Sketchpad	*TI technology*	*TI technology; Maple*	*technology*
➢ Math 540: Introduction to Mathematics Education Research (19)	➢ Math 522: Numerical Approach to Calculus (18) - *TI technology*	➢ Math 521: Statistics and Data Analysis (16) - *freeware statistical package R*	➢ Math 524: Number Theory and Cryptography (14)

Note: Additional courses were also offered to address specific credentialing needs:
Math 300: Sets & Logic (5)
Math 140: Elementary Statistics (1)

The San Joaquin Valley Mathematics Project,
California State University, Fresno (SJVMP-CSUF)

The San Joaquin Valley Mathematics Project (SJVMP) partnered with California State University, Fresno and the California Mathematics Project (CMP) to establish the SJVMP-CSUF STIR Project targeted at addressing the needs of professional development in hard-to-staff schools. The leadership team for the SJVMP-CSUF site is heavily involved in CSU, Fresno's Mathematics and Science Teacher Initiative (MSTI) endeavor which has been a logical and exciting extension of the MSTI projects. SJVMP-CSUF offers opportunities for professional growth, collaboration, and development for mathematics teachers at both the middle and high school levels with the expectation that teachers would remain at their school sites for longer periods. Activities include courses and workshops to develop and deepen teachers' conceptual understanding of mathematics content and the use of alternative pedagogical strategies to convey content to students in a more meaningful way. In the summer of 2007, 24 teachers participated in a weeklong summer intensive institute focused on mathematics content and developing collegial relationships among participants. Teachers were also trained in the use of varying technologies related to mathematics classrooms, such as The Geometer's Sketchpad, and spent time collaborating to create meaningful lessons using the new technology. During the first year, 25 teachers were exposed to Japanese Lesson Study (Lewis, 2002) during monthly Saturday training sessions and moved into the second year with well-established teams to collaboratively plan and teach specific mathematics concepts. Teachers drew from the mathematics content and alternative instructional approaches they learned during professional development sessions to work together in developing, teaching, evaluating, and revising meaningful mathematics lessons. Many participants commented in their annual logs as to the effectiveness of Lesson Study and the mathematics content coursework in developing their understanding of how to better teach mathematics in their own classrooms. SVJMP-CSUF provides opportunities for professional growth for participants through attendance at professional conferences and workshops, and offers college course units that participants may apply toward a graduate degree or an increase in their annual salary. This addresses one factor in retention (teacher compensation), but the primary goal of this project is the development of a supportive work environment in which teachers feel valued, connected, and that they are making a difference; an even more important factor in teacher retention.

The SJVMP-STIR Project focused on integrating technology-based instructional strategies and tools into professional development activities over the course of three years to encourage the use of such tools in the classroom in an effort to build students' conceptual understanding of complex mathematics. The Lesson Study Approach was an effort to increase teacher collaboration and sharing of ideas while integrating such technology practices in the classroom. The first year of professional development focused on teachers' understanding of mathematics content, how to incorporate hands-on instruction utilizing manipulatives, checking for understanding, and unique strategies for English Language Learners. The second two years, participants were given extensive training and field practice using alternative methods of instruction including the use of graphing calculators, smart boards, document cameras, GeoGebra, The Geometer's Sketchpad, and other instructional tools to enhance student understanding of Algebra and Geometry through the use of technology.

The fourth year is focused on developing the role of teacher leaders identified within the first three years who have the potential to maintain the programs put in place beyond grant funding. Teacher leaders will be invited to attend and submit results of their action research at the 2010 National Council of Teachers of Mathematics National Conference in San Diego, CA. The fifth year will include a culmination of teacher action research with classroom teachers presenting the results of their participation in Lesson Study to share with other teachers in the Central Valley.

STRIVE - San Diego State University, Imperial Valley

STRIVE (Supporting Teacher Retention for Imperial Valley Educators) is another one of the 10 sites of the California-wide STIR project, based at San Diego State University, Imperial Valley. Imperial County is in the southeastern corner of California, along the Mexican border. It is one of the poorest counties in the state. Almost 90% of the population is Hispanic. Agriculture is the dominant employer. The unemployment rate is one of the highest in the country. Many of the K-12 students here come from families in which the parents are uneducated and speak little or no English. In standardized math tests, Imperial County schools consistently rank among the last in California. The local schools suffer from a chronic shortage of qualified math teachers. Unable to attract outside talent, they are forced to hire math teachers from among the local population. Few of these have degrees in mathematics. Having grown up here, these teachers have no experience with standards other than those they were held up to in these same failing schools when they were taught there.

Like the other sites, STRIVE's professional development consisted of intensive summer institutes and academic year follow-up. Given the glaring lack of subject matter competence among local teachers, STRIVE's focus is on content-driven professional development, supported by pedagogy. In particular, we emphasize problem solving and justification, and deep conceptual understanding and reasoning. The math content is currently taught by the site director, and the pedagogy by two teacher leaders.

STRIVE was not set up around technology as a primary theme. Yet a fair amount of technology has snuck in, some introduced by STRIVE staff, some by the participating teachers. For example, we have a collaborative website on Google Sites, where STRIVE staff and participants can post teaching materials and links to their favorite educational websites. We have had a workshop on the use of graphing calculators given by a guest lecturer. We have looked at educational games, such as KENKEN and Math Jeopardy, and built online student surveys. We of course use PowerPoint presentations in the workshops and spreadsheets to study student achievement. Over the years, the teachers in STRIVE have formed a learning community. They often learn more about educational technologies from each other than from STRIVE staff.

Here is a more detailed description of the professional development STRIVE has engaged in since 2007:

- In year 1 (2007/08), we had a 40-hour intensive summer institute spread over a two-and-a-half week period. Most STRIVE teachers taught in their regular district-run summer schools in the mornings, while attending STRIVE workshops in the afternoons. The workshops were approximately evenly split between adult-level math content and pedagogy/teaching strategies, with the two aligned as much as possible. The math content covered numbers and operations with particular focus on reasoning and justification, and connecting college-level math with that taught in grades 7-12. The pedagogy addressed teaching English-learner populations, using student assessment data to inform instruction, student-centered teaching, and a variety of teaching techniques, such as mental math, the use of white boards by students, group discussion, etc. Participating teachers were observed in their summer school classrooms by STRIVE staff and coached.

  During the subsequent academic year, STRIVE teachers engaged in another 60 hours of professional development by attending a few refresher workshops and completing individualized follow-up activities. The latter included taking classes at SDSU-IV on math content or pedagogy, peer observation and coaching, etc.
- In year 2 (2008/09), STRIVE intended to follow a similar model to year 1. But shortly after the intensive summer institute began, a large-scale investigation by the SDSU Research Foundation into alleged mishandling of funds resulted in the suspension of all grant-funded activities at SDSU-IV. Needless to say, this greatly interfered both with the professional development and the research activities. STRIVE resumed activities in Jan 2009 with a series of workshops throughout the spring to make-up for the missed training of the summer institute. The theme of the math content was problem solving with emphasis on creativity and non-standard approaches. The pedagogy part introduced further teaching techniques, such as the use of graphic organizers and Venn diagrams. Individual follow-up and the completing the research logs fell victim to the grant investigation. This is why no log data is available for this site during year 2.
- In year 3 (2009/10), STRIVE offered another 40-hour summer institute while running its own summer academy for 7-8th grade students in the Calexico Unified School District. The latter was necessitated by the economic downturn, which resulted in the elimination or at least drastic reduction of districts-sponsored summer schools. The math content was algebra both in the summer institute and the academy, with emphasis on reasoning and justification. The pedagogy included work with manipulatives, such as algebra tiles and balance scales, and student-centered activities such as the Algebra Walk. The majority of STRIVE participants taught in our own summer academy in the mornings. In order to encourage creative teaching and experimentation with the new techniques, they taught in teams of two in small classrooms, and had to design their own syllabus and a pre and post-test for their students.

  Academic year follow-up included a series of workshops similar to the summer institute on a variety of math topics, such as combinatorics and geometry, and pedagogical approaches such as discovery-based learning. STRIVE teachers also designed their own follow-up activities with an emphasis on leadership. These were mostly done in small teams and included preparation of students for math competitions, organizing a math competition, lesson study, and cooperative lesson planning.
- Year 4 (2010/11) started with a 24-hour summer institute for a new cohort of teachers, paralleling that in year 1 in topics and organization. Except this time, the two teacher leaders were recruited from among the STRIVE veterans. One of the current teacher

leaders used to run a web-development business, and capitalizes on this expertise by introducing a variety of technological tools, such as online student surveys and flash-based educational games. The new cohort continues to attend workshops on numbers and operations during the academic year. There are also academic year workshops for both the new and the veteran cohorts covering further math (e.g. geometry) and pedagogy (e.g. clickers) topics. STRIVE is continuing with leadership development by sponsoring a mini-grant competition for teacher-based initiatives. In an attempt to transition funding to the districts, applicants are encouraged to seek matching funding from their administrators.

- Year 5 (2011/12) is dedicated to data collection, research, and dissemination of the results. No professional development activities are expected.

RESULTS and DISCUSSION

Part I: A quantitative look at log responses

The tables below provide percentages of log responses that mention technology over the three year longitudinal study across all four sites identified. Results include self-reported teachers' goals (collected early in the school year), opportunities, challenges, and needs/demands as participants were juggling their own teaching with participation in the CMP STIR project activities.

Table 1. Teacher goals over three years in relation to technology given in percentage of responses and collected from the questions:

LOG		**Year 1, Log 1 = "What are your goals with respect to teaching math for this coming year?"**	**Year 2, Log 1 = "What do you hope to do differently in your classes the coming year?"**	**Year 3, Log 1 = "What do you hope to do differently... ?"**
UCLAMP	Percentage Technology:	1/19 = 5.26 %	53%	51%
CSUB	Percentage Technology:	4/24 = 16.6%	9/22 = 40.9%	5/24 = 20.8%
SJVMP	Percentage Technology:	2/22 = 9%	2/21 = 9.5%	12/22 = 54.5%
STRIVE	Percentage Technology:	1/16 = 6.3%	N/A	6/17 = 35.3%

Goals to incorporate technology in the teaching and learning of mathematics show a dramatic increase at some point during the span of three years in all four sites. However this increase does not necessarily occur at the same time and is dependent on the point at which technology became integrated in the model of Professional Development. For instance CSUB immersed its participants early through intensive coursework that allowed participants to engage in higher level mathematical learning through the use of integrated technology. Concurrently, participants' goals to provide the same for their students peaked during support Year 2 as the following comment illustrates:

"In STIR, we mostly use graphing calculators to complete assignments and labs, so it is important to give H.S. students access to the graphing calculators to prepare them for higher mathematics."(CSUB)

The percentages of CSUB participants' goals for using technology decreased in Year 3, indicating a shift from a goal to something experimented with. For UCLAMP, the emphasis on technology was evident during the second summer of intervention and follow-ups, at which point participants' interest in trying out technology in their classrooms also reached high levels which were sustained in Year 3. For SJVMP's participants however, the desire to implement technology-based lessons and develop technology-embedded learning environments only became evident in the third year's responses since the integration of the tools into the professional development activities was more progressive, and established through the development of a growing professional learning community focused on Lesson Study with an emphasis on using Dynamic Geometry Software. This tendency is also true for STRIVE participants who experienced the formation of a tight-knit learning community of beginning teachers who readily share educational resources, including technological ones, with each other.

Table 2. Teacher opportunities for technology use given in percentage of responses and collected from the questions:

LOG		**Year 1, Log 3 = "What opportunities and obstacles in teaching math are you experiencing...?"**	**Year 2, Log 2 = "What opportunities are you experiencing in your teaching?"**	**Year 3, Log 2 = "Think back to the time before you participated in STIR. How are you teaching differently...?"**
UCLAMP	Percentage Technology:	0/13 = 0%	8%	14%
CSUB	Percentage Technology:	1/21 = 4.7%	5/22 = 22.7%	3/19 = 15.8%
SJVMP	Percentage Technology:	0/22 = 0%	3/22 = 13.6%	1/22 = 4.5%
STRIVE	Percentage Technology:	1/15 = 6%	N/A	4/13 = 30.8%

A first look at the numbers above shows an increase for all four sites from Year 1 to Year 3 in teachers' perception of technology use in the classroom as an opportunity. However, here again, two of the sites reached a peak during Year 2, which tapered down by Year 3. This trend is paralleled by the "Favorite lesson taught" table below. UCLAMP, the site that focused on systematically integrating the TI-NSpire as a single technology through targeted Professional Development, had more success in fostering a progressive increase in the perception of technology as a classroom opportunity. In addition, it is interesting to notice that for STRIVE, the site where technology was not an integral part of the original project design, log responses show higher percentages of technology mentioned as opportunity than for other sites. This could however be a result of having such low numbers of participants. Also a careful look at the log entries shows that the type of technology STRIVE teachers implement are essentially instrumental for classroom presentations such as PowerPoint or Webpages, and do not necessarily interact with the teaching and learning of specific mathematical concepts.

Table 3. Teacher <u>challenges</u> in using technology given in percentage of responses and collected from the questions:

LOG		**Year 1, Log 3 = "What opportunities and obstacles in teaching math are you experiencing...?"**	**Year 2, Log 1 = "What challenges do you expect to face in realizing your plans?"**	**Year 3, Log 1 = "What challenges do you expect to face in realizing your plans?"**
UCLAMP	Percentage Technology:	0/13 = 0%	19%	32%
CSUB	Percentage Technology:	1/21 = 4.7%	5/22 = 22.7%	6/24 = 25%
SJVMP	Percentage Technology:	2/22 = 9%	0/22 = 0%	6/22 = 27.3%
STRIVE	Percentage Technology:	0/15 = 0%	N/A	4/17 = 23.5%

Perceived challenges show an increase in all sites as teachers become more aware of the difficulty to turn technology use into positive gains in student learning and achievement. Such realization is clearly illustrated in the following quote:

> *"I've designed many lessons that I thought I would like and then found that it was a waste of time that I didn't have to begin with. The students don't learn any more than if I taught directly out of the book, plus they don't follow directions. I was looking forward to using computer labs and Ti-Nspire activities with both Algebra 1 and Geometry this year, but every time I try to work such a lesson in, we end up even further behind. With benchmarks and state tests coming up, this is a problem." (CSUB - Challenge)*

Access to technology to meet teachers' goals for using it in their classroom is also often mentioned as a challenge beyond their realm of influence:

> *"Acquiring technology; such as, class set TI-nSpire is a challenge" (UCLAMP - Challenge)*

> *"I also believe technology would get the students more involved, but unfortunatly I don't have much access to any*." *(SJVMP - Challenge)*

With some participants being more successful when receiving administrative support:

> *"I want to incorporate more technology into my teaching. I believe that computer software such as Geometer's sketchpad, graphing calculators, and electronic whiteboards can have a profound effect in improving math instruction for all students, but especially for English Language Learners. My principal agrees with me and has allowed me to order class sets of graphing calculators for three teachers and an electronic whiteboard for the math department. My participation in CMP STIR [..] was instrumental in helping convince the principal that this was a good investment of scarce funds."(SJVMP – Goal and Opportunity)*

Unlike the leveling patterns noticed in goals and opportunities for some of the sites, challenges encountered in using technology tend to increase across all four sites from one year to the next. When comparing the percentages in Tables 2 and 3 to the goals collected in Table 1, these results shed light on a shift from what teachers wanted to achieve to something that was accomplished and is reflected upon, and also indicate a desire to utilize what was learned during the professional development in their own classrooms, with some reservations regarding the efficacy of such strategies. The more experience teachers gain in using instructional technologies, the more critical they become of their adequate use in the mathematics classroom.

Table 4. Teachers demand for support in technology given in percentage of responses and collected from the questions:

LOG		**Year 1, Log 3 = "What support would help improve your success as a teacher of mathematics?"**	**Year 2, Log 2 = "What additional support would you like to see from CMP STIR?"**	**Year 3, Log 3 = "On a scale of 1-4, with 1 as low, rate each of the components relative to how important you think they are to a program of support."**			
				1	2	3	4
UCLAMP	Percentage Technology:	0%	25%	0	1 (8%)	9 (69%)	3 (23%)
CSUB	Percentage Technology:	2/21 = 9.5%	1/22 = 4.5%	1/20 (5%)	5/20 (25%)	9/20 (45%)	5/20 (25%)
SJVMP	Percentage Technology:	2/21 = 9.5%	1/18 = 5.5%	3 (15%)	5 (25%)	6 (30%)	6 (30%)
STRIVE	Percentage Technology:	2/15 = 13.3%	N/A	0 (0%)	2 (12%)	3 (19%)	11 (69%)

The demand for support in technology use is low over the years, although participants consider it an important component of the Professional Development they receive. This could be a sign of success of the models in addressing participants' perceived needs in support for Technological Pedagogical Content Knowledge. Other types of support that received higher ratings include: Management, Pedagogical Content Knowledge, Subject Matter Content Knowledge, Networking for Support, Lesson Study, and Time. Technology-related demands are often monetary and connected to the challenge of access identified above, but some participants do request more targeted training as well:

> *"I would like to see CMP STIR offer more about the technology that is available and how we can get our hands on it for classroom use. It would also help if the project can convince our district of the importance of providing funds for technology in the classroom."(SJVMP - Demand)*

Table 5. Mention of technology in favorite lesson taught given in percentage of responses

LOG		Year 1, Log 6 = "Briefly describe a lesson that you taught which you especially liked during this past year"	Year 2, Log 4 = "Describe one of the lessons you taught this fall that you especially liked"	Year 3, Log 3 = "Describe one of the lessons you taught this fall that you especially liked"
UCLAMP	Percentage Technology:	1/13 = 7.7%	4/10 = 40%	3/13 = 23%
CSUB	Percentage Technology:	3/22 = 13.6%	7/25 = 28%	3/20 = 15%
SJVMP	Percentage Technology:	0/19 = 0 %	4/22 = 18.2%	2/20 = 10%
STRIVE	Percentage Technology:	2/13 = 15%	N/A	2/16 = 12%

The trends observed in Table 5 parallel the perception of technology as a classroom opportunity form Table 2. In Year 1, participants may not have had a chance to incorporate technology into their classroom in a satisfactory way, or they may have been more receptive to other strategies offered by the program, such as the introduction of hands-on activities with manipulatives into their teaching. By Year 2, there is an increase in the self-reported efficiency and enjoyment of using technology as a teaching tool across the four sites. However the increase tapers off during Year 3, at which point teachers might have been able to gather evidence on students' achievement and/or understanding of concepts learnt through the use of technology. This could be attributed to the difficulties, and often the absence of aligning assessment items with the new classroom framework of teaching and learning in a technology-embedded environment. For UCLAMP, this could also be attributed to the low numbers and a slight increase in total number of responses in Year 3 compared to Year 2. In a future study it would be interesting to examine at what point a teacher feels confident enough in their own ability to incorporate technology into their lessons in a manner that students can still perform satisfactorily on traditional assessments. A parallel study should also look into adapting assessment materials to the growing emphasis on using instructional technologies for concepts acquisition in mathematics.

During a study that looked at teacher's acquisition of TPACK, researchers observed the following stages in teachers' development when learning to use a specific technology in their mathematics classroom (Niess et. Al., 2009):

> *1. Recognizing (knowledge), where teachers are able to use the technology and recognize the alignment of the technology with mathematics content yet do not integrate the technology in teaching and learning of mathematics.*
>
> *2. Accepting (persuasion), where teachers form a favorable or unfavorable attitude toward teaching and learning mathematics with an appropriate technology.*
>
> *3. Adapting (decision), where teachers engage in activities that lead to a choice to adopt or reject teaching and learning mathematics with an appropriate technology.*
>
> *4. Exploring (implementation), where teachers actively integrate teaching and learning of mathematics with an appropriate technology.*

5. Advancing (confirmation), where teachers evaluate the results of the decision to integrate teaching and learning mathematics with an appropriate technology.

At the *Recognizing* stage, teachers may not yet use technology to teach mathematical concepts, but recognize the need to engage in professional development and learning to use the technology. These teachers would mention their goal to integrate technology in the classroom, even though this may not be reflected in their actual practice. The increase in technological goals across the sites shows that a growing number of STIR participants became aware of the importance technology could play in their teaching.

> *"I had always believed that manipulative and technology were very important in the classroom but I wasn't aware of how I could implement them. Because of my experience in the summer strive I was able to team-teach and be exposed to how other teachers incorporate these elements into their classrooms." (STRIVE - Recognizing)*

The *Accepting* stage involves teachers who actively engage in Professional Development opportunities to learn how to integrate technology in their teaching of mathematics, although the transfer to classroom practice may be very limited and still focused on technology as a teaching aid rather than a learning tool.

> *"I especially like to go to workshops where they teach how to implement technology into the classroom because it helps today's digital students." (STRIVE - Accepting)*

Through their enrollment in the program, STIR teachers are by default exposed to such PD and the rates attributed to technology in Table 4 show that they value the experiences received. For example, CSUB's MATM is technology-focused; mathematical concepts are discovered and discussed through inquiry-based activities encouraging participants to try new teaching strategies with their students as one teacher indicates:

> *"I have used Geometer's Sketch Pad with my LCD projector onto my classroom whiteboard. I learned how to use the program in my class thru the CMP STIR program." (CSUB - Accepting)*

At the *Adapting* stage, teachers may start considering technology as an opportunity or a challenge in their ability for implementation. They may have tried to adapt ideas collected during workshops to the needs of their own classroom, and begin to assess the results of such endeavors on their students' achievement and learning. At this stage, teachers are able to identify mathematical topics in the curriculum that could benefit from a technology-embedded environment. The trends observed in perception of technology as an opportunity, paralleled by the mention of technology in favorite lesson taught, provide evidence that several teachers' confidence in their technological skills has reached a point where they feel comfortable using it with their students and understand the benefits of introducing such activities in their classroom. However the growing percentages in teachers finding the use of technology in the classroom to be a challenge indicate that these efforts may not have always been successful.

> *"Scatterplots and modeling via a linear regression. This lesson is great for using technology. I would like to get more real world raw data sets to work with. My experience in the program gave me a better understanding of regression and features to use with advanced, graphing calculators." (CSUB - Adapting)*

The *Exploring* and *Advancing* stages assume that teachers have fully integrated technology in the teaching and learning of mathematical concepts through activities that allow ample time for students to explore mathematical concepts in a more self-directed way. It is difficult to identify from the logs CMP-STIR participants who have fully adopted such facilitator roles in their classrooms. Such concerns with this study would most likely necessitate classroom observations that focus on the transfer of techniques learnt in the PD to classroom implementation. Unfortunately we do not have this kind of data available.

Part II of this paper examines individual teachers' responses to shed more light on the relationship between Professional Development models and Teachers' TPACK acquisition.

Part II: A qualitative look at log responses

Gathering log responses over the past three years provides insights into participants' acquisition of Technological Pedagogical Content Knowledge. A qualitative look at these responses assisted us in better interpreting the percentages provided in Part I. In Part II we examine the effects of each site's model of professional development. First, we classify the reported use of participants' technology into general technology for teaching purposes versus technology specifically geared to the teaching of mathematical concepts. Second, we identify the development stages of participants engaged in the PD and examine teachers' relationship to the technology they use is examined with reference to the TPACK development framework. We focus on the favorite lesson taught over the three years, as well as Year 3, Log 1, which specifically inquires about the role of problem solving, manipulatives, and/or technology in terms of participants plans for teaching, math content or what they expect from their students. Finally, the coding of responses is further split into the following 4 TPACK Standards as suggested by Growth et. Al. (2009):

D = Design and develop technology enhanced mathematics learning environments and experiences
F = Facilitate mathematics instruction with technology as an integrated tool
A = Assess and evaluate technology enriched mathematics teaching and learning
E = Engage in ongoing professional development to enhance technological pedagogical content knowledge.

TPACK Standards **D**, **F**, and **A** imply that teachers have demonstrated evidence of integrating TPACK in their work, thus pertain to teachers who have reached stages 3-5 (Adapting, Exploring, or Advancing) in their development process of using technology in the classroom. Several participants responses reflect a real concern and appreciation for category **E** as can be seen in sites responses below.

UCLAMP: The Professional Development model at UCLAMP focused on getting participants familiar with the use of TI-technologies, with a particular emphasis on integration of TI-Nspire activities in the classroom. Consequently, logs mentioning use of technology mostly focus on these mathematics-specific instructional tools, although some also experimented with more general tools such as online resources and videos.

"I introduced my students to Lure of the Labyrinth...I created accounts for them all..." (UCLAMP, Year 3)

Student access appears as a major concern for UCLAMP participants who integrate technology in their classroom. Some teachers experiment with the TI-Navigator for enhanced formative assessment, and several of them have identified areas in the curriculum where their students can benefit from individual uses of the Ti calculator series. Teachers are able to **F**acilitate activities that promote students' engagement with algebraic topics through calculator-based explorations.

> *"I have found using graphing calculators to be an excellent and engaging tool for teaching and re-teaching. I especially find that students learn more advanced topics and skills related to graphing when they use the graphing calculator." (UCLAMP – Adapting, Year 3 – **F**)*

> *"I taught a lesson on the shifts that affect the graphs of quadratic functions. We opened the lesson with the students exploring on the graphing calculators." (UCLAMP – Exploring, Year 2 – **F**)*

The use of visual aids for improved communication and presentation is also important.

> *"One lesson that I really enjoyed was a graphing calculator lesson using the TI-Nspire and the Smartboard." (UCLAMP – Adapting to Exploring, Year 2 – **D**)*

Hands-on technologies that enable each student to individually explore and make sense of mathematical concepts have been adopted by several UCLAMP participants as key components in their Algebra classroom. The high percentages of quotes mentioning technology for the UCLAMP Professional Development model is evidence that most teachers have at least accepted technology as a necessity to be integrated in their work, and several have taken the steps necessary to adapt their teaching to incorporate TI-technologies for all students with success.

CSUB: After three years taking courses in the Masters of Art for Teaching Mathematics, where CSUB participants were immersed in learning advanced mathematical concepts in a technology-rich environment, the transfer to classroom implementation is highly focused on technology uses that aim at enhancing mathematical experiences for students. The choice of technological tools is often specific to the learning of mathematics such as TI-technologies, or Dynamic Geometry Software, although some participants also find that an active board can provide excellent support to an interactive classroom presentation, especially when teaching concepts that benefit from a variety of visual representations.

CSUB participants quickly moved beyond the *Recognizing* stage of TPACK development, probably as a result of their own learning experiences through technology. Mastering the instrumentation became as much of a necessity for their own advancement in the program as it was for instructional support in their classrooms. Their immediate involvement with the complexity and dynamics of learning mathematical content with technology through an inquiry-based approach, together with the enthusiasm of the site directors for such a learning environment, certainly helped motivate a quick shift in beliefs and attitudes about using these tools in the classroom, while enabling the confidence necessary to give it a try.

> *"I taught a lesson on Medians, altitudes, and perpendicular bisectors of a triangle using geometer sketchpad. I like the fact that I was able to use technology to make the lesson more interesting. Because of the classes I am taking with CMP STIR, I learnt the*

*Sketchpad Program really well. It made me confident enough to utilize it during a lesson."(CSUB – Recognizing, Year 1 - **E**)*

Most investigations engaging CSUB participants in their coursework were not directly applicable to their own classroom teaching however; participants often had to be creative to adapt the knowledge they received during the Professional Development to implement in a High School setting. The Dynamic Geometry course did provide activities that the participants could immediately reproduce with their students, thus helping teachers move through the *Accepting* stage of TPACK development, underlining the immediacy and flexibility provided by the use of technology in developing and checking conjectures through generation of multiple examples:

*"With my geometry classes I had them discover the Euler line in triangles. Each person was assigned a type of triangle and they had to draw in the altitudes, medians and perpendicular bisectors of all of the sides. [..] When they came to an agreement for their triangles, they made posters and presented out to the group on their findings. Finally, we went to the computer lab and redid the constructions using GSP to test the conjectures that each group made about the significant points." (CSUB – Accepting to Adapting, Year 2 - **F**)*

Teachers who tried to apply the advanced knowledge of mathematical content gained in their coursework do acknowledge an improvement in their competence both from a subject matter and from a pedagogical standpoint. This spills over to their Technological Pedagogical Content Knowledge as they begin to identify areas of the curriculum for which students benefit from the use of technology in the classroom:

*"Scatterplots and modeling via a linear regression. This lesson is great for using technology. I would like to get more real world raw data sets to work with. My experience in the program gave me a better understanding of regression and features to use with advanced, graphing calculators." (CSUB – Adapting, Year 1 – **D&E**)*

The weekly lab setup for every course at CSUB provides participants with first hand experiences with investigations and collaborative work. The perceived benefits of such a teaching and learning environment is apparent when teachers celebrate the use of such strategies in their own classrooms and their role becomes one of a facilitator guiding the activities students engage in with the technology as active learners.

*"I put together an exponential function worksheet that allows students to create exponential function models, (growth/decay/ logistic) determined by the information given. [..] Students use graphing calculators to analyze their model, make predictions, and find intersection points to solve for unknown exponent variables. Students gain experience working with the calculators and help each other complete the task."(CSUB – Exploring, Year 2 – **D&F**)*

As demonstrated in these quotes, CSUB participants have evolved in their abilities to **D**esign and **F**acilitate technology-rich environment. They often attribute these gains to their **E**ngagement in the STIR program. It is not evident however that any of these participants have reached the same levels of sophistication in using technology for **A**ssessment purposes. Also, several of them are still speaking in terms of "showing" or "illustrating" with technology instead of mentioning direct student interaction with the technology. The use of terms such as "explore", "create", “analyze”, “predict”, “discover”, “involved”, and “interested” in relation to students activities when engaged in technology-based learning have become more common throughout the years though. This provides a good illustration of variations in individual teachers’ TPACK development across the themes of Curriculum and Assessment, Learning, Teaching, and Access (Niess et. Al., 2009).

SJVMP: The first year of SJVMP STIR focused on differentiation strategies for reaching diverse students, with an emphasis on English Language Learners who strongly benefit from kinesthetic and visual approaches to teaching and learning mathematics. This was followed by an examination of Dynamic Geometry Software and graphing calculators’ capabilities through Lesson Study implementation in Year 2 and Year 3. These experiences determined a direction for SJVMP teachers when looking at utilizing technology in their classroom. The power of visualization brought to students through these interactive technologies is highly noted by these teachers, as is the ability to connect mathematical lessons to real-world situations.

> *I taught a Geometry lesson in which students were discovering the "Euler Line" and making a conjecture about the relationship between the Euler Line, the Incenter, and the types of triangles that placed the incenter on the Euler Line. It was fun to have students constructing circumcenters, centroids, and orthocenters of triangles with a compass and straight edge and then discover the fact that they always end up on a line. It was also cool how we were able to make the same construction on Geogebra and quickly verify our conjecture about the behavior of the incenter (SJVMP – Accepting to Adapting, Year 3 –* ***F****)*

The use of general tools such as Promethean boards and Jeopardy games on PowerPoint for instructional purposes are mentioned by several participants as efficient ways to engage students and support their understanding through visual representations.

> *When I was teaching my Algebra 2 class about Domain and Range, I brought out the human sized graph and I assigned each student to a point. While one group of students were the points, the others not only saw how the other students were moving on the graph, but I also had it on the promethean board. When I would call out domain, the students would walk towards the x-axis, and we would discuss the graph. When I called out range, the students would walk towards the y-axis and we would discuss the graph. (SJVMP – Exploring, Year 2 - F)*

Full integration of the technology as a way to enhance the teaching and learning of mathematics is evident for several SJVMP participants. The creative ways in which they choose to integrate these new strategies in their classroom demonstrate a concern for high levels of student engagement with the mathematics in collaborative settings where teachers stand as facilitators. The thorough choice of tasks based on their relevance to students’ interest and on the the level of cognitive demands asked of the students indicates TPACK development at the *Exploring* or even *Advancing* stages.

> *Lesson plan on Graphing Equations.*
> *-Used google maps of the Fresno Area and students formulated equations from the map.*
> *-Students worked in groups to come up with equations from the given map. Students transferred the map to own paper. So different groups had different equations.*

-Students were engaged and worked together great.
*-Students explored how to come up with equations. (SJVMP – Advancing, Year 2 - **F**)*

Some SJVMP teachers have build confidence in their abilities to innovate with technologies for enhanced students understanding through careful lesson planning, and for appropriate development of students' mathematical habits of mind through representation and communication.

*To teach the area formulas for the special quadrilaterals I had prepared an Activstudio flipchart with illustrations of the quadrilaterals and how we can cut or move parts of them to form a rectangle, for example. Students then had a visual representation of a potentially abstract formula. I enjoyed using the Activstudio software as a tool in my classroom and the animations that it allowed for me to incorporate in my teaching. (SJVMP – Adapting, Year 2 – **D**)*

Here again, terms such as "engaged", "explored", "formulated", "verify" when describing students actions in the classroom are further evidence of teachers concerns with setting and sustaining learning objectives for their students that reach higher levels of Bloom's taxonomy.

<u>STRIVE</u>**:** Teachers participating in the STRIVE project were not specifically trained in the use of a particular classroom technology, although technology clearly played a role in the building of the community through the sharing of Web resources and PowerPoint presentations. Some of these activities were adapted by participants as models for changes to enact in their classroom. These more general types of classroom technologies help STRIVE participants to feel more confident in their abilities to engage students with the content while they teach, or as instructional support outside of class. These teachers are still predominantly the users of instructional technologies in their classrooms with limited access to their students:

"One of the lessons I did was about finding the slope of a line using a PowerPoint presentation." (STRIVE, Year 1)

"I would like to include my homework in a webpage." (STRIVE, Year 3)

After three years of intervention, several of these teachers are still at the *Recognizing* stage of developing TPACK as some self-reported challenges surface:

*"The first challenge is the technology because I myself I am not good at it. I want to learn to do presentations using PowerPoint with lots of animations. I would like to connect media to my presentations" (STRIVE - Recognizing, Year 3 - **E**)*

Others however have incorporated technology for effective pedagogical changes, and moved on to the *Accepting* stage of TPACK development:

"One of the most important parts in my case is checking for understanding using multiple ways as white boards, hand signals, and electronic devices." (STRIVE - Accepting, Year 3)

"During the summer session, my goal was to practice using technology with the students to incorporate it more during the present school year." (STRIVE - Accepting, Year 3)

Finally one STRIVE participant who is clearly more versed in technology as a support for his professional practice looked at other possible integration of technologies in his work:

*"I am planning to use Web based assessments for my students and upload my student's homework to a webpage so they are able to download it at any time." (STRIVE – Year 3 – **E**)*

Part III: Other insights on technology

In part III of this paper, we provide insights on how a focus on technology-rich professional development models may support teachers in the dimensions of student-engagement, community-building, leadership, and ultimately retention through accrued confidence in one's abilities and efficacy.

Throughout the logs, technology was often mentioned as promoting student-engagement, which many participants identified as a major challenge in the first year of intervention. Engagement strategies are always highly rated among teachers self-reported needs and constitute an area that can and should be improved upon early in the teaching career. Providing these new teachers with the skills and knowledge of how they can turn a classroom of blank stares into an engaged community of learners will go a long way towards realizing the rewards necessary for committing oneself to a long-term stay in the teaching profession.

"I especially like to go to workshops where they teach how to implement technology into the classroom because it helps today's digital students." (STRIVE, Year 1)

"I enjoy giving students opportunities to work with technology in the classroom. Students used higher level thinking skills to interact with others and analyze their functions and graphs." (CSUB, Year 2)

"The students were fascinated by the GeomSketchPad. They were involved and interested." (CSUB, Year 3)

Technology was also mentioned as a Community builder through online lesson-share, list-serve, emails, and the collaborative work on common lessons for SJVMP participants, and on common investigations for CSUB teachers. When prompted about which aspects of the CMP-STIR Program they valued the most, many participants applauded the networking and community established by the Program, which allowed them to break their classroom isolation while becoming acquainted with new resources through their peers from other schools. At times, technology was clearly instrumental in fostering this sense of sharing and belonging:

"We also created a website where we can contribute with teaching tools like power point, worksheets and how different teachers teach the same lesson using different strategies"(STRIVE, Year 3)

Some participants found technology to be a catalyst for leadership opportunities such as conference presentations, website management, and mentorship.

"I am the mentor. We discuss the use of various strategies and technology tools. Student engagement is also a big issue with new teachers." (STRIVE, Year 1)

"Become the Liaison for a Web Development Project for our STRIVE Institute."(STRIVE, Year 3)

Others provide ideas on how technology can further help so sustain the established community in years to come:

"More email contact with suggestions and ideas from other members of the project and from the leadership." (SJVMP, Year 2)

"It would be nice to get interesting articles from research papers at least once a month about effective teaching techniques (math) so that I can practice them. it takes time to Google for a reliable and useful info about teaching. Reading such articles would be very useful." (CSUB, Year 3)

These activities are still in progress at many sites across the CMP-STIR project. For example CSUB participants were invited to participate in the planning of a T^3 Regional Institute held on University grounds in September 2010 where they also had a chance to present in practitioner sessions:

Modeling, Regression Analysis, & Systems of Equations with the TI-83/84
1 - Investigating data relationships & Regression Analysis: Real world bivariate data will be investigated numerically/ graphically to determine if there is a significant pattern in the relationship. These patterns will then be used to attempt to find a mathematical equation that relates the bivariate data via Regression Analysis. If a reasonable model is found, this model will be used to discuss effectiveness and limitations with respect to interpolation and extrapolation. 2 - Systems of Equations – Investigating real world word problems using matrices: Real world data will be investigated using situations involving multiple variables and multiple equations that can be modeled by a system of equations. Various investigative methods will be discussed to solve the systems with a focus on how to set up the system in matrix form, then use matrix operations to solve the system. (CSUB – TPACK Advancing, Leadership, Year 4)

Ultimately, teachers who experience high levels of efficacy with technology in their classroom and in their work are more likely to experience higher levels of classroom autonomy through increased creativity in their lesson planning. This can also provide greater opportunities for leadership initiatives on-site as other teachers in the same school may become interested in receiving similar Professional Development. Increased confidence in one's ability to engage students meaningfully with the mathematics, while being able to reach out to an outside community for support, and seeing one's influence broaden through leadership incentives, are all factors that contribute to a greater likelihood of teachers remaining in the classroom. Through carefully designed Professional Development, we have ways of influencing these factors.

CONCLUSIONS

We described four different models of professional development aimed at supporting teachers in their work while promoting TPACK acquisition. Our analysis shows that each model responded to various needs for the participants and brought them further in their development towards incorporating technology efficiently in the mathematics classroom in order to meet the TPACK Standards. We conclude by highlighting trends characteristic to each site.

UCLAMP focused on a specific piece of technology, the TI-Nspire, through intensive summer workshops and follow-ups, enabling participants to become very comfortable with the interactive and investigative capabilities of the device. This in turn promoted transfer and adaptability to the classroom setting which participants describe as teaching opportunities in greater numbers each year. In particular, UCLAMP participants tend to use technological tools that all students have access to such as handheld devices that put the technology directly into the hands of the students for them to interact with the material.

CSUB provided a greater variety of technologies for the project participants to become familiar with for their own growth as learners of mathematics while taking courses in the MATM. This familiarity with the tools helped participants adapt their teaching strategies and experiment in their own classroom with confidence. However frustrations with luke-warm results and the realization that knowledge of the instrumentation does not necessarily ensure the success of a teaching episode is apparent in the growing number of participants who mention technology as a challenge in their teaching. CSUB participants do recognize that technology goes a long way towards engaging students, with varying success in its implementation.

SJVMP participants were actively engaged in the design of lessons through a Lesson Study approach to Professional Development. The collaborative and reflective work of teachers on curriculum and ways to best engage the students meaningfully with the material that naturally emerges from a Lesson Study group comes across through the self-reported use of technology by participants. SJVMP teachers who did refer to classroom uses of technology in their logs had clearly thought about carefully designing tasks that put high levels of cognitive demands on their students.

STRIVE did not focus on technology use. But the logs reveal that the participating teachers are very much interested in learning about incorporating technology into their teaching and recognize it as an opportunity to better engage students. Many of them already use standard educational technologies, such as presentation tools, and online tools, although the use of technologies specific to mathematics teaching and learning is much less common. Others who are less experienced are eager to learn. In fact, technological resources are frequently shared peer-to-peer in the learning community of teachers that STRIVE forged over the years.

As sites work towards increasing leadership opportunities for their participants, other ways of integrating technology meaningfully in the work of mathematics teachers emerge, including greater access to online resources, sharing of Technological Pedagogical Content Knowledge through conference presentations, and use of electronic networking for sustaining and enhancing the Professional Community. We hope that all of these can have a positive influence on mathematics teachers when faced with decisions to stay or leave.

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