2016

Impact of collaborative teaching on K-12 mathematics and science learning

Tonya D. Jeffery
Stephen F Austin State University, tonya.jeffery@sfasu.edu

Cherie A. McCollough

Kim Moore

Impact of Collaborative Teaching on K-12 Mathematics and Science Learning

Dr. Tonya Jeffery, Dr. Cherie A. McCollough and Ms. Kim Moore

A national effort is underway to transform teacher education program practices and produce effective and highly qualified teachers for 21st century classrooms. This effort prescribes providing preservice teachers (PSTs) with authentic clinical experience in the field that connects what is taught in teacher preparation programs with what they do in the K-12 classroom. Bridging the gap between theory and practice requires teacher education programs work in partnership with school districts, redesigning teacher training to better serve prospective teachers and their students (NCATE, 2010).

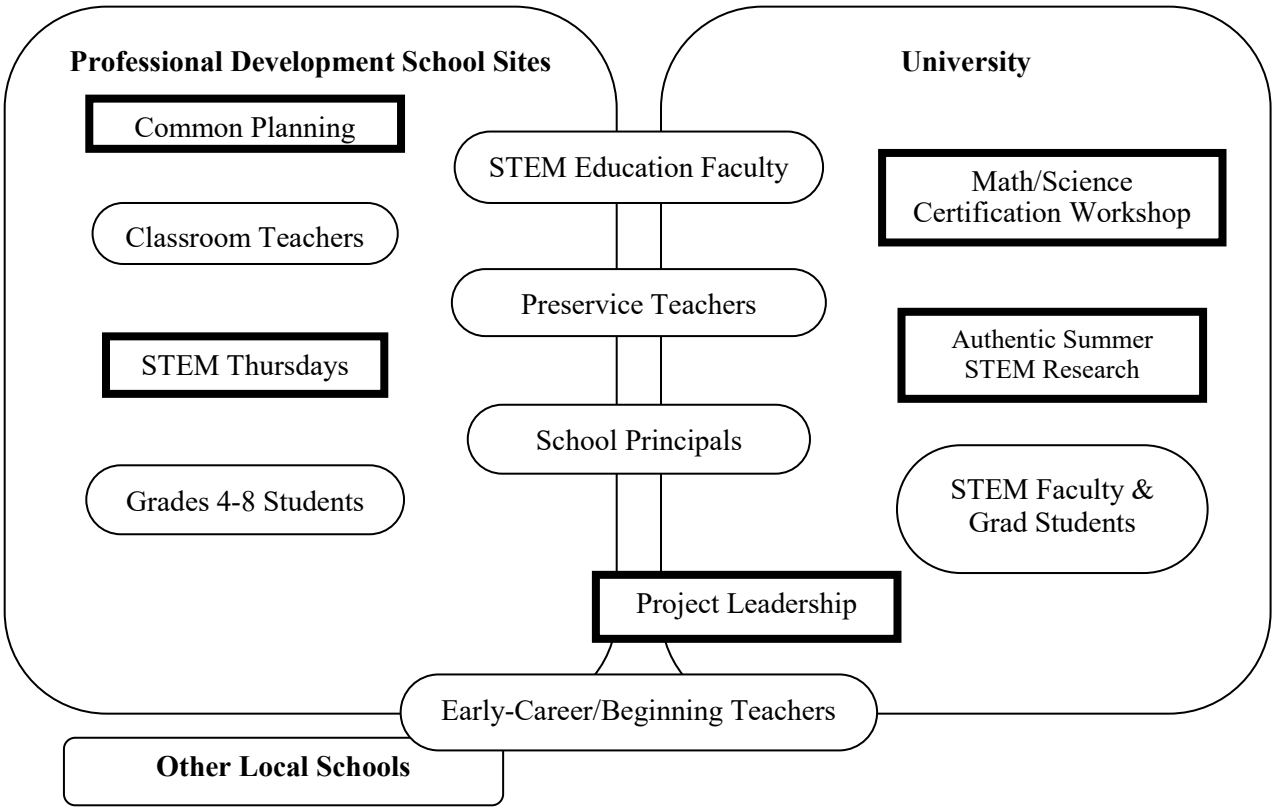
Efforts are also underway to reform K-12 mathematics education (CBMS, 2010) and science education (NGSS, 2013). The Mathematics and Science Partnerships (MSP) established by the National Science Foundation (NSF) and the U.S. Department of Education (DOE) brings together teachers, mathematicians, and mathematics educators, illustrating the potential of such collaborations to improve teachers' practices, their understanding of mathematical knowledge for teaching, and their students' learning (Mathematical Sciences Research Institute, 2009). The Principles to Actions and Next Generation Science Standards (NGSS) provide an opportunity for educators to change their practices in order to enhance the learning of mathematics and science concepts for all students (National Council of Teachers of Mathematics (NCTM), 2014; NGSS Lead States, 2013). However, this can present challenges for PSTs as they begin to learn about these standards and try to apply them to classroom teaching. In addition, incorporating inquiry-based teaching and learning through hands-on, minds-on activities can also be a daunting task for inservice teachers, especially with tensions involving state and district mandates, high-stakes testing, and accountability policies. These challenges often influence teachers' desire to implement engaging lessons that allow K-12 students to show their innovation, creativity, and imagination in disciplines like mathematics and science.

Ideally, PSTs should not only hear about evidenced-based practices, but should see them being taught and modeled in a K-12 classroom. Many elementary generalists (EC-6) are uncomfortable with teaching mathematics and science and are more likely to avoid these subjects (Newton, Leonard, Evans, & Eastburn, 2012). Furthermore, some teachers conduct science and mathematics activities without understanding the process behind those activities (Windschitl, Thompson & Braaten, 2007). There is a great need for teachers who are strong in both content and pedagogy, especially at the grades 4-8 level. Professional development for preservice and inservice teachers is most effective when it is hands-on and when it takes into account local context (Darling-Hammond, 2009). Still, many inservice teachers have attended external professional development events regarding best practices, but have not actually seen them modeled in the classroom setting. The National Council for Accreditation of Teacher Education's (NCATE) Blue Ribbon panel on clinical preparation and partnerships has noted the critical role of field experiences in the development of PSTs and new teachers and praised co-teaching as a model for linking theory and practice in preparing teachers to teach (NCATE, 2010). Co-teaching occurs when the mentor teacher and preservice teacher work together in the planning, delivery, and assessment of instruction. Such co-teaching narrows the gap between theory and practice, develops pedagogical content knowledge, and fosters reflective practice (Murphy, Scantlebury, & Milne, 2015).

As STEM faculty educators working to prepare the next generation of highly qualified teachers, we are part of a school-university partnership seeking to bridge the gap between theory and practice by implementing best practices in the elementary and middle school classrooms. This article provides evidence-based data on the utility of a STEM site-based professional development program, the Elementary Teachers Engaged in Authentic Math and Science (ETEAMS) program (Jeffery, McCollough, & Moore, 2015). It discusses the ETEAMS program's professional development organizational model (see Figure 1), the benefits of co-teaching, and how the program's innovative strategies have led to increased student achievement and more well-prepared beginning teachers.

The article then highlights one of the ETEAMS lesson plans collaboratively developed by the school-university partners. The inquiry-based lesson utilizes the 5E learning cycle (Bybee et al., 2006) and helps fourth and fifth grade students develop mathematical problem-solving skills, critical thinking skills, and content knowledge while learning about the concepts

Figure 1. Organizational structure of professional development school program. Rectangles indicate major activities, ovals indicate participant groups, and proximity of ovals to rectangles suggests typical level of involvement.



of measurement and conversions.

Program Description

The ETEAMS program is a 3-year initiative funded by NSF. This collaborative program brings together preservice and inservice teachers, grades 4-8 students, teacher education professors, and research scientists, with the purpose of increasing student achievement, confidence, and interest in mathematics and science. Working in close partnership with school districts, it also seeks to revamp teacher preparation and better serve prospective teachers and the students they teach by enhancing teaching and learning in grades 4-8 with innovative instruction. Three sites – two elementary and one middle school -- serve as professional development schools for the education, research, and teacher preparation components of the initiative. All are situated in low, socioeconomic status (SES) urban areas, with predominantly Hispanic populations of students who are underrepresented in the STEM fields. When this initiative began, all three schools were in 'Improvement Required' status (students failed to meet minimum test scores on state standardized exams) according to NCLB. These schools needed research-based strategies to improve competencies in mathematics and science teaching and learning.

This transformative professional development model provides authentic experiences in mathematics and science to enhance PSTs' content knowledge, pedagogy, and self-efficacy in teaching these disciplines. The model consists of four components (see Figure 1): 1) common planning 2) STEM Thursdays 3) certification workshops and 4) authentic research experiences. The ETEAMS STEM Thursday component is featured in this article. The goal of STEM Thursdays is to increase content knowledge, self-efficacy, and interest in 4-8 students as well as preservice and inservice teachers.

A unique feature of the ETEAMS program is its professional development organizational model. Here, PSTs collaborate with in-service teachers and university STEM faculty to plan, deliver, and assess high-quality, inquiry-based, hands-on integrated math and science curriculum to grades 4-8 students during STEM Thursdays. The facilitation of collaborations

by university faculty, team teaching of STEM Thursday lessons by preservice and inservice teachers and university faculty, and the supervision of preservice teachers before, during, and after STEM Thursday lessons by university faculty, have been critical to increasing student achievement in math and science, improving PSTs' self-efficacy, and to the initial success of the program at the partner schools, as outcomes show.

Research Questions

As a MSP project, the ETEAMS program was driven by research questions informed by the theoretical framework surrounding the social cognitive approach to teacher education. The research questions emphasized for this article are: 1) To what extent does participation impact math and science performance among 4-8 students?, and 2) To what extent does participation influence the self-efficacy in grades 4-8 STEM content and STEM interest in grades 4-8 students and teachers?

Methodology

This mixed-methods study analyzed elementary and secondary preservice teachers' self-efficacy in teaching math and science to grades 4-8 students during the implementation of the STEM site-based professional development (PD) program as well as the 4-8 students' performance in math and science. It also looked at 4-8 students' interest and self-efficacy in math and science. The study employs quantitative data from state assessments in math and science as well as STEM Thursday post-teaching surveys. Qualitative data was retrieved from focus group interviews, individual semi-structured interviews, classroom observations, and STEM Thursday post-teaching surveys.

Participants

Context of the study

The College of Education teacher preparation program is part of the professional development schools (PDS) model that features inherent and rich collaborations between the P-12 schools, districts, and university faculty. During the final year of the teacher preparation program, PSTs complete a required yearlong field experience. The first semester of PSTs' field experiences is the field base course, which focuses on the pedagogy and professional competencies of teachers. Students complete a general pedagogy course, which does not supply a sufficient amount of information for the specialized needs of the math and science disciplines. A K-12 school campus (partner school) hosts the field base course on-site at and taught by a university site professor. The PSTs spend two days per week for 14 weeks working with their university site professor on pedagogical skills, and time in assigned K-12 classrooms implementing teaching strategies and techniques with students. Coteaching with their mentor teacher is a significant feature of the teacher preparation program (Educator Preparation Handbook, 2013). The second semester of field experiences is the student teaching semester, in which the PSTs spend five days a week for 14 weeks in a partner school.

The ETEAMS program was offered to PSTs interested in increasing their math and science content knowledge in grades 4-8. The PSTs participated in this research study during their required yearlong field experience. In addition to completing the course expectations during field basing and student teaching, participants met after school to plan three inquiry-based lessons for STEM Thursday. The research participants were assigned to research partner schools and took their field-based courses over consecutive Fall-Spring semesters. The first author taught one of the field base courses during the fall and spring semesters in which some of the participants were enrolled. There are approximately 25 PSTs per year participating in the ETEAMS program.

STEM Thursday Model

Each semester, three to four STEM Thursdays were planned at each of the partner schools. During STEM Thursdays, preservice and inservice teachers along with university faculty collaborated in planning and delivering hands-on lessons in mathematics and science. A team teaching model was used where all the adults were actively engaged with students throughout the lesson. At the elementary school level, lessons were taught in 3rd, 4th, and 5th grade classrooms to between 125 and 250 students a day. At the middle school level, lessons were taught in 6th, 7th, and 8th grade to approximately 600 students. At each school, approximately 12 teachers were divided into teams of 3-4 people to plan and deliver instruction for a targeted grade level.

Planning for STEM Thursdays began with the statewide objectives along with the district's scope and sequence. Two planning meetings took place prior to the implementation of these lessons. At the first meeting, the inservice teacher shared the topics that have already been taught, so that everyone was aware of what prior knowledge the students are bringing to this lesson. This project uses the 5E model of inquiry-based instruction to develop lesson plans (Bybee et al., 2006). The goal of the first planning meeting is for everyone to leave with an outline of each of the parts of the lesson: Engage, Explore, Explain, Elabo-

rate, and Evaluate.

A Google doc with the template for the 5E lesson plan was created so members could continue to communicate. Google docs allowed team members to give feedback and collaborate on the creation of the lesson plan. This fostered shared decision-making and ownership of the team-taught lesson. Between planning sessions one and two, team members sent out ideas for components of the lesson, including short videos, card sorts, foldables, graphic organizers, and inquiry-based activities. They also completed a section of the lesson plan which included listing all necessary materials, key vocabulary, directions the teacher will give, links to resources, and probing questions. All components of the lesson were uploaded on the project's website.

At the second meeting, the group reviewed the lesson plan, looked over the instructional materials, discussed the lesson, and made modifications as needed together as a team. The team also assembled materials for the lesson if necessary. The PSTs walked through the lesson, practicing each part of the 5E lesson plan. They discuss possible misconceptions and created answer keys for the activities. During this final meeting, team members decided what specific roles they would each play during the lesson. Often they took responsibility for leading one of the 5Es. During small group activities, all of the preservice and inservice teachers and university faculty circulated among the groups, facilitating learning through engaging the students in probing questions.

Reflection was an essential part of this collaborative process since the goal was continuous improvement. Informal debriefing occurred between class periods. Decisions were made on the spot about what pieces needed to be removed or perhaps completed the following day due to time constraints. At the end of the day, all of the collaborative teaching teams met to reflect on what worked well, what did not work as planned, and ways to improve the lesson. The university faculty guided the preservice teachers in conversation about engagement and student learning. We believed this collaboration in planning, teaching, and reflecting fostered continuous improvement in the preservice teachers' professional development and helped them make sense of the intersection between theory and practice. In addition to the face-to-face reflection session, an electronic evaluation was sent out after each STEM Thursday to the preservice and in-service teachers. This assessment of the STEM Thursday lesson implementation provided quality feedback to the project faculty and directed the project's improvement for future STEM Thursday events. It included the following questions, which the responders rate on a scale of 1 to 6: (1) How engaged did the students seem during the presentation? (2) Was the presentation at an accessible content level for the students? (3) Did the presenters seem prepared? (4) Did the presenters seem to have a strong understanding of the content? (5) Did the presenters support students to experience success? (6) Was this presentation a good use of class time?

Gallon Man Goes to Space

The *Gallon Man Goes to Space* is a STEM Thursday lesson that was taught two consecutive years at different elementary school sites in 4th and 5th grade with modifications following the first year. Planning began with the following math objectives that included measurement and metric conversions, measurement of length, width, time, liquid volumes, mass, and money using addition, subtraction, multiplication, and/or division as appropriate.

At the initial planning meeting, teachers utilized the *National Council of Teachers of Mathematics (NCTM) Illuminations Lesson*, 'Water, water,' as a resource, and they adapted the material to fit the grades 4 and 5 learning objectives. The lesson began by engaging the students with the following questions: "What are some uses of water in our everyday life?" and "What is your estimate for how much water the average American uses in space every day?" To assess prior knowledge, the teachers asked the students the following questions:

- What units do we use to measure volume?
- What is the relationship between cups, pints, quarts, and gallons?

After a group discussion, the teacher informed the students that in space, astronauts are only allowed to have 6 gallons of water per day. She asked the students to think about why they have this limit as they watch a NASA video clip on an astronaut brushing his teeth in space.

The students then explored the following problem to continue their investigation of the relationship between capacity measurement units: "Given that the astronauts are allowed 6 gallons of water in space, how many cups of water would the astronauts be permitted to take?" In groups, the students (with the help of a team member) were given the following tools: a cup, a pint, a quart, and a gallon. The students poured cups into pints, pints into quarts, and quarts into gallons, discovered the relationships between each unit of measurement and worked on a so-

lution to their problem. The lesson continued with the whole group explaining what they have discovered. Then they used this information to create a three-dimensional (3D) gallon man. An empty gallon of milk is the starting piece for building the gallon man. Using Velcro as an adhesive, four quart oil containers were added to represent the arms and legs. Eight sixteen- ounce cups (pints) were then attached to the quarts to create hands and feet. Finally, sixteen eight-ounce cups were attached as fingers and toes (see Figure 2).

After the students explored conversions using hands-on materials, they explained what they have learned. Students watched a video, 'A Cup Grows Up' to reinforce the learning of the measurement equivalencies through a song. The video adds to the students' content knowledge by showing that there are eight ounces in a cup. After the video, the students completed their gallon man astronaut individually.

During the elaboration phase of the lesson, students were ready to look at the mathematical relationships between the different units of measurement. One of the teachers led the group in completing the first table. Students were looking for patterns to find the rule that governs the input and output columns on their tables. In some cases, students needed to work backwards. They had the rule and needed to determine what units of measurement would follow that rule. For example, on one chart they saw that four _____ is equivalent to one gallon. They needed to fill in the heading 'quarts' for that column. In the 5th grade version of this lesson, the students also answered two-step word problems relating to astronauts' water usage in space. One of the questions from this handout asked:

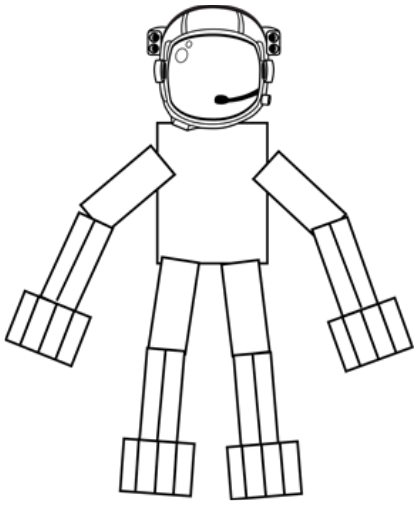
It is recommended that each astronaut drink two quarts of water per day. Andy has consumed 16 gallons of water. Assuming he drank two quarts per day, how many days has Andy been in space?

The lesson ended with an evaluation. The second year a PowerPoint with multiple-choice questions was added to help students prepare for standardized tests. The teacher led the whole group in responding to these questions. In order to maintain a high level of engagement and active participation among all students, the teacher encouraged the students to respond to the questions by tapping their desk (once for A, twice for B) or by holding up their fingers (one finger for A, two fingers for B). If the teacher had access to a classroom response system, that could be used as well. After each question, students were called upon to explain their reasoning to the whole class. The questions incorporated the greater than and lesser than sign, which students have previously learned. As students were responding to these questions, the teachers were formatively assessing knowledge acquired during this lesson.

Results of Gallon Man Lesson

The process of collaboratively planning, teaching and evaluating led to an engaging lesson that students were able to enjoy and learn. The real world context of the lesson allowed students to make connections while learning new materials. While the responses to the evaluation survey were positive overall, the data gathered revealed consistent growth between the first and second years. When asked,

Figure 2. Two-dimensional (2D) and three-dimensional (3D) Gallon Man.



"How engaged did the students seem during the presentation," in year one, 40% of the teachers responded with a 4 and 60% responded with a 5. In year two, the 28.6% of the team said 4, 42.9% indicated a 5, while 28.6% answered with a 6. When responding to the question, "Did the presenters support students in experiencing success," year one 20% indicated a 4, 20% a 5, and 60% a 6. In year two, 100% of the responders gave this question a 6.

Comments added to the quantitative assessments included, "I loved the integration of several different content areas including measurement, multiplication, division, as well as science." Another reported, "This was a good way to combine several objectives (measurement and tables)." When giving feedback on the revised lesson in year two, an inservice teacher commented, "College students were great at asking probing questions and making the elementary students think!"

The Gallon Man lesson incorporated one of the eight mathematical teaching practices recommended by the NCTM (2014), which is using and connecting mathematical representations. Students gained a deeper understanding of the relationships among capacity measurements through two and three dimensional models. In addition, they experienced the connection between measurement units by actually pouring water and transferring the water from one container to another. Since the lesson was grounded in a real world problem of water in space, the students were able to make connections between science and mathematics as well as see how their learning has applications outside of the classroom.

Results of STEM Thursdays

Standardized test scores among the partner schools consistently increased during the two years of this project. In grades 5 and 8 math, the passing rate the year prior to the implementation of this initiative was 43%. This increased to 59% in year one and 67% in year two. In grades 5 and 8 science, the baseline passing rate was 42%. This increased to 58% in year one and 63% in year two.

During individual interviews and a focus group led by an external evaluator, preservice and inservice teachers had the opportunity to reflect on STEM Thursdays. They reported collaborative planning led to a sense of ownership and increased confidence. The PSTs said:

> *We actually design the lesson. Of course, we get the TEKS from the teachers, but we design the lesson, we design the—the activities and then we—in turn teach it to our individual classes.*

> *The STEM Thursdays are really helpful because we get to collaborate, and like I said, Dr. Anderson and Ms. Smith (pseudonyms), when they collaborate with us, we don't feel as though they're any different than we are. We feel kind of like we're their peers, and the respect that they give us and the ideas that they give us—it just feels like it's a true collaboration.*

> *With our university class, we learned how to do discovery type of labs but with the ETEAMS program, we actually saw how to do it. Actually had to do it and get practice with that.*

The inservice teachers valued the modeling of innovative lessons in the classroom. This motivated them to try such practices on their own. An in-service teacher shared:

> *I definitely am more open and kind of try to think outside the box a little bit more. . . I definitely try to look elsewhere to still cover the same information, but in a fun, engaging way.*

The teachers also reflected on how the preservice teachers, graduate students, and STEM faculty are great role models for the 4-8th grade students. The teachers explained:

> *When you bring in those other students or people who are doing something in the sciences, it's exposure for the kids that I don't think they otherwise would have had.*

A second teacher agreed that students had experienced increased interest in STEM careers because of their exposure to people involved in STEM:

> *They're exposed to people outside of their standard teacher who are involved in things like this. So, you know, I think it has helped some students have a better perception of—or value of STEM careers.*

Both the inservice and preservice teachers noted the level of enthusiasm of the elementary and middle grades students. The students enjoyed lessons that involved a high level of activity and interaction with their peers as well as their teachers. Due to the number of adults in the classroom, the students received more immediate feedback, which led to deeper learning.

Conclusions

The STEM Thursday model benefits all the stakeholders by pooling resources, materials, and expertise.

By working in partnership with the inservice teachers and school administrators, STEM educators and faculty attained a better grasp of how to present educational theories to PSTs; thus helping them to bridge the gap between theoretical constructs and practical applications in the classroom through these authentic experiences. Especially for those faculty that have been far removed or disconnected from K-12 schools for some time. This ensures that the courses they teach are relevant and responsive to the everyday realities of the profession. In-service teachers benefit in multiple ways. They receive research based, high quality professional development situated in their teaching context. During the lessons, they have many extra hands in the classroom, which allows instruction to be differentiated, meeting the needs of diverse learners. Best practices are modeled, which encourages the inservice teachers to continue utilizing these strategies outside of STEM Thursdays. Not only are best practices modeled, but inservice teachers begin to appreciate the power of collaboration in all aspects of teaching including evaluation and reflection.

The school district has the advantage of hiring novice teachers that have high levels of content knowledge, pedagogy and self-efficacy in teaching math and science. These beginning teachers also have a deep appreciation for collaboration. This partnership in planning, teaching, and reflecting encourages a shared vision for teaching and learning at the schools and contributes to the success of all.

Implications and Recommendations

With the ongoing tensions of responding to accountability measures through standardized testing, it is important to find innovative strategies teachers can utilize in the classroom for inquiry-based teaching and learning to enhance student achievement. It is also critical that Colleges of Education prepare their future teachers to be successful by making sure theory is consistently grounded in the context of authentic teaching. Collaborations among Colleges of Education, Science and Engineering, as well K-12 school districts lead to increased student achievement as well as novice teachers that are more confident in teaching math and science content and capable to rising to the challenges of educating all children. Furthermore, the STEM Thursday is a model of a well-supervised field experience program that provides critical input for strengthening clinical preparation of our preservice teachers.

Although this team teaching model was driven by the need for preservice teachers to have authentic experiences to learn both content knowledge and pedagogy, this model could be used to strengthen the quality of teaching and learning at all schools. In-service teachers could benefit from being able to collaboratively plan, participate in team teaching, and engage in thoughtful reflection. While this level of collaboration requires an investment of both time and money, the authors contend that this investment is well worth the outcome of more prepared, confident, and knowledgeable teachers and students.

References

Conference Board of the Mathematical Sciences. (2010). *The mathematical education of teachers II: Issues in mathematics education* (Vol.17). Washington, DC: Mathematical Association of America. www.cbmsweb.org/MET2/met2.pdf

Darling-Hammond, L., Wei, R.C., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad* . Stanford, CA: National Staff Development Council and the School Redesign Network at Stanford University.

Educator Preparation Program Handbook (2015). Texas A&M University-Corpus Christi, College of Education. Corpus Christi, TX: TAMUCC.

Jeffery, T.D., McCollough, C., & Moore, K. (2015). Growing STEM roots: Preparing preservice teachers. *Academic Exchange Quarterly, 19*(3), pp. 102 -111.

Mathematical Sciences Research Institute. (2009). *Teaching teachers mathematics: Research, ideas, projects, evaluation: Critical issues in mathematics education* (Vol. 3). Berkeley, Calif.: Mathematical Sciences Research Institute.

Murphy, C., Scantlebury, K., & Milne, C. (2015) Using Vygotsky's zone of proximal development to propose and test an explanatory model for conceptualizing coteaching in pre-service science teacher education, *Asia-Pacific Journal of Teacher Education*, *43*(4), 281-295. doi: 10.1080/1359866X.2015.1060291

National Council for Accreditation of Teacher Education. (2010). *Transforming teacher education through clinical practice: A national strategy to prepare effective teachers*. Washington, DC: NCATE.

National Council of Teachers of

Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: Author.

Newton, K. J., Leonard, J., Evans, B. R., & Eastburn, J. A. (2012). Preservice elementary teachers' mathematics content knowledge and teacher efficacy. *School Science and Mathematics*, *112* (5), 289–299.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states.* Washington, DC. National Academies Press. www.nextgenscience.org/next-generation-science-standards

Water, Water. Retrieved December 23, 2015 from https://illuminations.nctm.org/Lesson.aspx?id=1141

Windschitl, M., Thompson, J., & Braaten, M. (2007, April). *How novice teachers appropriate epistemic disciplinary discourses for use in classrooms*. Paper presented at annual meeting of the American Educational Research Association. Chicago, IL.

Acknowledgements

This work was supported by the National Science Foundation under Grant No. 1321319. Any opinions, 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 or the authors' institutions.

About the Authors:

Dr. Tonya Jeffery is an assistant professor of science education in the Department of Teacher Education, College of Education at Texas A&M University in Corpus Christi. Her scholarship focuses on STEM teacher preparation, self -efficacy, and retention.

Dr. Cherie A. McCollough is an associate professor of science education in the Department of Life Sciences, College of Science and Engineering at Texas A&M University in Corpus Christi. Her research interests include science content pedagogy and culturally relevant teaching strategies in science

Kim Moore, M.Ed., is the project manager of externally funded initiatives in the Department of Mathematics and Statistics, College of Science and Engineering at Texas A&M University in Corpus Christi. After spending 21 years in the K-12 classroom, she is now focused on developing the next generation of teachers.