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Walking the Walk: Authentic Science and Mathematics Research Conducted by Preservice and Inservice Teachers

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Theoretical Framework

The Problem: Lack of Adequately Trained STEM teachers

There is a critical shortage of middle school STEM (Science, Technology, Engineering and Math) teachers, especially in low income and high minority schools. Contributing factors include teachers' inadequate science and mathematics content knowledge and a principle focus on language arts that limits the time for other projects in the early grades (Marx & Harris, 2006). Fewer than half of elementary teachers have completed the minimum number of recommended science and mathematics courses and many elementary school teachers hold significant misconceptions regarding science and mathematics (Capps, Crawford, & Constas, 2012).

Improving Teacher Preparation in Mathematics and Science

In order to view math and science as meaningful and feel competent in these subjects, young children need to be involved in experiences that involve mastery, positively contributing to the students' self-efficacy (Bandura, 1997). However, the current paradigm that is embraced by the majority of educators uses the scientific method in a linear fashion which often allows the proliferation of distorted images of scientists. Teachers are often conducting science and mathematics activities without understanding the process behind those activities (Windschitl, Thompson, Braaten, & Stroupe, 2012). To make mathematics teaching more conceptual and less procedural, mathematical professional development must address teacher's dimensions of mathematical knowledge rather than focusing only on pedagogy or generic teaching skills (NCTM, 2010). In addition, research tells us we must engage learners deeply with science

content while using authentic science practices (NRC, 2012). The following professional development project and associated research study explains one way we can engage preservice teachers (PSTs) more deeply in scientific and mathematical thinking for teaching and learning.

Exposing Preservice Teachers to Authentic Science and Mathematics Research

Authentic science can best be experienced by conducting authentic, testable, revisable, explanatory and generative research in authentic settings that include an active-learning modality (Windschitl et al., 2012). However, elementary teachers are rarely given the opportunity to work with scientists and mathematicians to learn how science and mathematics is conducted. The TEX (pseudonym) project investigators believed that authentic science and mathematics investigations can best be explored and experienced by participating in real research performed by university scientists and researchers while including this investigative research element in the PD model. This research report describes a model where elementary preservice teachers receive professional development in teaching conceptual mathematics and science. This model involves not only teaching and learning in the elementary and middle school classroom, but also participation in authentic research (real research being conducted for data analysis and subsequent publication) with mathematics and science university faculty.

South Texas University's (STU) TEX Initiative

STU's TEX (pseudonyms) initiative is funded by a 3-year grant to test an innovative preservice strategy for bolstering the number of elementary to middle level science and mathematics certification and teaching pathways, assisting them with the certification process by augmenting their science and mathematics content knowledge. The program provides empirical evidence on early career fellowships aimed at increasing the preservice elementary-to-middle-school-STEM pathway. The TEX program created a partnership with preservice and inservice teachers and district administrators with science and mathematics higher education faculty to

strengthen the development of teacher leaders. In addition, the investigators created a comprehensive evaluation program.

One of the pieces of the TEX initiative provides an authentic summer research experience (explained in the following paragraphs). As a research-based effort, investigators are studying the impact of the TEX initiative through a mixed methods matched-group research design addressing grades 4-8 students, pre- and inservice teachers, school, district, and university outcomes in relation to views on the Nature of Science (Abd-El-Khalick, Bell & Lederman, 1998), as well as self-efficacy, interest, and achievement in STEM, and indicators of the quantity, quality, and diversity of grades 4-8 mathematics and science teachers. The following report describes the authentic summer research experience piece of the TEX initiative.

Authentic Research Experience

A unique and critical feature of the TEX model is the authentic research experience. Because school based science investigations usually occur in a one hour class in a middle grades classroom, students are often indoctrinated with the belief that there is one, linear scientific method and have little to no understanding about scientific theory, scientific law, and the tentativeness of scientific knowledge (NGSS, Appendix H, 2013). Therefore, teachers and students often have the false impression that scientific research is fairly time limited that that most scientific investigations result in the hypothesis being supported by the evidence. The TEX authentic research experience is designed to help preservice and inservice teachers improve their knowledge about the nature of science, their comfort level with engaging in scientific inquiry, and deepen their knowledge of both scientific content and processes. Students experience how mathematics is used in scientific research through statistical analysis, mathematical modeling of biological data, and computer sciences.

Preservice and inservice teachers in the TEX program engage with scientists at STU for a minimum of 30 hours during the summer STEM research experiences where participants contribute to original scientific research projects. PSTs work with masters' and doctoral science students in the laboratory and in the field, as well as with university mathematics and science faculty members. The following outlines some of the research subjects and methods that are used for data collection.

Methods and Data Collection

Recruitment of Fellowship Participants

In late Spring, annual recruitment and selection of ETEAMS cohorts occurs in parallel with generalist elementary education majors' field placement process. Materials are shared with all Senior elementary education majors (approximately 300 annually), and those with demonstrated success and interest in STEM content are invited to apply. The project supports three cohorts of 40 fellows over three years to prepare for middle levels science and mathematics teaching.

TEX inservice/preservice teacher participants work with masters' and doctoral science students, mathematicians and science faculty to collect and analyze data for modeling Gulf Coast ecological phenomena, including the depositional history of tidal flats, organic matter input into Nueces Bay, composition of seagrasses in South Texas, shell variation of oysters, the microlayer of the bay, and the neurological system of a researched invertebrate, *Aplysia californica*. TEX authentic research experiences naturally lead to new questions, new experiments and new ideas for the classroom. In anticipation of this, the summer STEM research experience includes a summative meeting with STEM faculty, PSTs and inservice teachers which focuses on making connections to the classroom and how the research experiences have impacted participants' views on the nature of science and mathematics. The participants in the authentic research are required

to keep a science journal, publishing two research logs on TEX's website that record their experiences in the lab and field as well as questions they have and ideas for creating classroom based lessons using the 5E instructional model (Bybee, Taylor, Gardner and Scott et al., 2006) that are uploaded and published on the TEX website. Preservice teachers work with inservice teacher leaders about the research experience, collaborative leading them to design the classroom experience. Graduate students also come to the schools and share their research experiences with teachers and students. These "talk to a scientist" segments become part of the lesson, allowing students to actually speak with the researcher about their experience, making connections to the lesson. By forming these relationships with professional scientists, the teachers have resource people that they can contact.

Much of the TEX research data on inservice and preservice teachers uses instruments and protocols from recent research, and the research design employs several existing instruments with published analyses of delimitations, reliability, and validity. Teachers' self-efficacy in mathematics and science are measured through annual administrations of the Science Teaching Efficacy Belief Scale (STEBI) (Enochs & Riggs, 1990) and the Mathematics Teaching Efficacy Belief Instrument (MTEBI) (Enochs, Smith, & Huinker, 2000), each of which includes subscales for outcome expectancies and self-efficacy (see Bleicher [2004] for structural analysis, reliability, and validity). Fellows and teachers' growth in pedagogical content knowledge in mathematics or science are measured through normalized gains on existing pre- and posttests developed for the mathematics and science workshops, as well as scores on the TExES mathematics 4-8 and TExES science 4-8 certification exams. Views on the nature of science are measured by the VNOS-C survey (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).

Implementation of mathematics and science instructional practices is assessed using composite scores from classroom observations by TEX staff and self-reports on the Survey of Instructional Practices (science, math, and administrator forms) from the Council of Chief State School Officers and the Wisconsin Center for Education Research (with support from grant agency). Qualitative data is gathered from annual focus groups with participants responding to open-ended questions regarding the research experience, self-efficacy and interest in mathematics and science.

Results and Conclusions

Qualitative Data

Focus group reports revealed that participants found the field topics engaging and challenging. They also learned that the scientific process is much more complicated than what is generally presented in textbook laboratories. While they had difficulty tying the field subject matter to classroom curriculum, science and mathematics education faculty were able to help them make connections. Selected comments included:

> "I think it made me more excited, to, to teach it. It definitely made me more excited to get into science, because…I was able to see the connects and it made me more excited to be in there."

> "And we'd go out there every single day and, you, I was in there in the lab and doing all that work with the different chemicals and stuff. And so, really the only thing I could think of it tie it back to the classroom, was how important procedure is for certain types of experiments."

"Yeah <field experience> is observation, it's not a worksheet."

"I was actually able to probe like the specific cell, brain cell that they were working on. So these little tiny microscopic probes and it was pretty cool."

Additional comments and illustrative photos will be presented at the conference.

Quantitative Data

Quantitative data collected included tests regarding teaching self-efficacy, science and mathematics content knowledge and the Nature of Science (see Methods section). In addition, the participants research logs have been evaluated using a metric specifically created to measure understanding of STEM content accuracy (as reported by the participants), STEM content depth (understanding of science and/or math content involved in project) STEM practices (level of skill utilized during the project), quality and quantity of grades math/science connections to classroom and overall presentation score. This data is currently under analysis and will be presented at the conference. To date, over 40 research logs and accompanying lesson plans have been uploaded to a public website. This information will be included in the presentation, as well as photographs of research, lesson plans and ideas that can be translated to 4-8 science and mathematics classrooms.

Discussion and Implications

Admittedly, the task ahead of PD facilitators and teacher educators is a challenging one, especially given the expectations of NGSS (Achieve, 2013) and the National Council of Teachers of Mathematics (NCTM, 2014). While it may be tempting to try and focus on only knowledge or beliefs, research indicates that attempting to impact both results in greater change (Loucks-Horsley et al., 2010; Lumpe, Szerniak & Haney 2012). This change does not happen

quickly and therefore, pre- and inservice teachers should be provided with extended experiences, frequent feedback and a strong, supportive professional learning community reinforced with structured mentoring to increase both knowledge and efficacy in science and mathematics instruction. The Professional Development model implemented in the TEX initiative incorporated authentic research experiences in the field and laboratory that increased self-efficacy, content knowledge and provided a much more accurate view of the the nature of science and scientific process.

As educators and researchers, we constantly reflect on our practice for personal and professional growth. As a team, we were able to support preservice and inservice teachers' growing knowledge of science and mathematics teaching and instruction to best benefit student learning. Results show that implementation of the TEX program's authentic summer research experience helped to better equip preservice and inservice teachers to prepare science and mathematics students in the ever changing world of our global society.

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