

**AC 2010-2311: TECHNOLOGICAL LITERACY IN A K-5 TEACHER  
PREPARATION PROGRAM**

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# Technological literacy through a K-5 teacher preparation program

## Introduction

Attaining a certain level of technological literacy in our society is important for a variety of reasons. In this extremely technologically-rich age, citizenry will need to participate effectively in our democratic society on a variety of complex problems; such as global warming, energy supply, quick-paced biomedical advances, complicated healthcare reform and statistical-based arguments galore. This will require a level of technological, quantitative and scientific literacy. One might call this STEM-literacy, where the literacy level not only includes literacy in each on the four components but also in how the four components work synergistically together. Additionally, technology/engineering can provide valuable contextual education settings resulting in effective learning (of math, science and “non-technical” subjects like history, social studies and language arts). At our institution, The College of New Jersey (TCNJ), it was felt that an effective place to impact technological literacy, as well as increase the effectiveness of teaching and learning is with future K-5 teachers. So, approximately 10 years ago a multidisciplinary science-technology-engineering-math (“STEM”) K-5 major was defined and implemented, where the teacher candidates receive a deep level of content knowledge in all four STEM components, as well as education tools for “integrated-STEM”.<sup>1</sup> The program is referred to as the Math/Science/Technology, or MST, program, even though all four elements of STEM are represented in the program. [That is, a more accurate name would have been the “STEM” K-5 program.]

An obvious potential benefit of the MST program is numerical in nature; an effective technologically literate K-5 teacher should impact the willingness to “think and learn technologically” for thousands of young students, and hundreds of colleagues. Another large potential benefit is pedagogical in nature and deals with, for example, deeper contextual learning and open-ended design/problem-solving. With deep experiences in all four areas of STEM, our K-5 MST graduates have high content knowledge and high skill levels in STEM, resulting in overall higher teacher effectiveness. Perhaps more importantly, MST program graduates have comfort (low anxiety) in a broad set of subjects and experiences.

In this paper we give a detailed description of (i) the K-5 MST program, (ii) a brief overview of a quantitative characterization of the program and (iii) unique research topics made possible with our K-5 STEM graduates and their students.

### *Summary:*

The K-5 MST program at our institution offers a unique opportunity both for increasing teacher effectiveness and K-5 student interest in STEM and non-STEM subjects. However, having a population of technologically literate K-5(8) teachers and teacher candidates also offers many unique research opportunities. [The definition of “technologically literate” here likely entails being literate to some degree in the S, M and T&E.] Leaving the teaching effectiveness benefits aside, a population of technologically literate K-5 teachers, and presumably their K-5(8) students, should enable technological literacy instruments to be better designed and calibrated. This has broad implications. Measurements of technological

literacy in MST and non-MST teacher populations could be used to determine what T&E skills and knowledge are required to achieve technologically literate K-5(8) students as well for achieving effective teaching. This also has obvious implications towards quantitatively defining T&E standards for teachers, K-5(8) students and eventually 9-12 students. The design and structure of teacher preparation programs as well as K-12 schools could also be impacted. Results of a variety of internal studies of the MST program have been completed and are also briefly reviewed in this paper. These initial characterizations center on quantifying the level of content knowledge [in S, T&E, M (and math anxiety)], necessary building blocks for STEM literacy as well as effective teaching. In this paper possible research topics surrounding the MST population are discussed in detail.

### **Program History**

Following the adoption of New Jersey's Department of Education (DOE) Core Content Standards in 1996, the Department of Technological Studies was asked to convene chairs from the departments of elementary education, mathematics, biology, chemistry, physics and the coordinator of "NJ Statewide Systemic Initiative to Improve Math, Science and Technology Education in K-12" to consider designing a new multidisciplinary major to fulfill a recognized need for more K-5 teachers with strengthened STEM skills. There was concern over the trade-off between disciplinary "depth" and interdisciplinary "breadth." However, this concern was overcome by creating the major with a broad "core" and a required in-depth "specialization." Three specialization areas are possible: (i) math, (ii) science (biology, chemistry or physics) or (iii) technology/engineering. The major was approved by our institution's Board of Trustees in 1998 and subsequently as a disciplinary major for education majors by the State's DOE in 2000. The MST major is one of several program offerings in the Department of Technological Studies within the School of Engineering. Other programs include a Technology/Pre-engineering education major and a Masters in the Art of Teaching. All majors are fully accredited by the National Council for Accreditation of Teacher Education (NCATE). Advising, recruiting and program requirements for the MST program are coordinated by the Department of Technological Studies. The Department of Technological Studies provides all of the T&E courses and has five full time professors and ~6 adjunct professors. Educational requirements and advising for the MST students are coordinated by the School of Education.

Four works set important context for the Department of Technological Studies curriculum and the design of the MST program: (i) Benchmarks for Science Literacy ("Project 2061"), (ii) Technological Literacy Counts, (iii) Standards for Technological Literacy (STL) and (iv) Technically speaking- why all Americans need to know more about technology.<sup>2-5</sup> These documents discuss the important role of teacher preparation in meeting educational goals in math, science and technology. STL states that technological literacy is critically important for the general population, not just for STEM-oriented persons. A STEM teacher preparation program is consistent with this philosophy, bringing deep S, T&E and M skills to an important group; teachers of impressionable K-5(8) students.<sup>6</sup>

### **Program description**

In addition to their disciplinary major, all K-5 majors at our institution must declare one of four elementary education majors: (i) Elementary Education, (ii) Early Childhood, (iii) Deaf

& Hard of Hearing or (iv) Special Education. All MST majors have the same core requirements but every student must also choose and complete a specialization. There are three choices for specialization areas; math, science (biology, chemistry or physics) or technology, giving a total of five specific specializations. Taking four successive classes (2009-2012), totaling 125 students, an assessment of specialization indicated that the technology and math specializations were chosen most often, each comprising ~35% of the total. Science specializations were chosen by ~16% of the students, while 12% were undecided. Past experience indicates that the majority of the undecided will likely choose a technology specialization. Prior to the MST program, the only STEM disciplinary majors chosen by K-5 students were mathematics and biology. The most popular science specialization chosen by MST majors is physics.

The MST program was designed to be structurally consistent with our K-12 technology education program. That is, the courses taken by MST majors are identical to those courses offered in our K-12 Technology/Pre-engineering education program. Our institution's technology education program has its roots in industrial education, dating back to the 1930's. A major revision of the industrial education program was completed in 1985 when the "technology education" major was created with an emphasis on studying the human designed world. The program was revised again in 2005 with a "pre-engineering" emphasis and is now referred to as the "Technology/Pre-engineering Education" program. The Technology/Pre-engineering education program integrates more math and science, enabling a higher level of analysis. This recently revised program also aligns well with more rigorous pre-engineering K-12 curricula [like Project Lead The Way (PLTW)]. A strong emphasis on the design processes exists through out much of the curriculum, including both understanding the steps as well as experiencing the process through design activities.

*(1) Curricular description:*

The MST major is a 32 unit (128 credits) baccalaureate degree with requirements generally divided into three areas; (I) Liberal Studies, (II) MST Core and (III) Professional.

(I) Liberal Studies [10 units]

Our institution has extensive liberal learning requirements that include history, arts & humanities, global studies, gender, race & ethnicity, community-engagement, a freshmen seminar experience, mid- and senior-level writing experiences, as well as requirements in science and quantitative reasoning.

(II) MST Core & Specialization [12 units]

The MST academic core consists of 8 units including Multimedia Design, Structures and Mechanisms, two additional science options, one additional math, two MST electives (fulfilled by taking M, S or T), and a course titled "Integrated STEM for Young Learners." Specialization courses require 4 units.

(III) Professional Courses [10 units]

MST education majors meet New Jersey's Certification requirements for a K-5 "highly qualified teacher." Courses include several literacy/literature courses, psychology, math and science methods and a series of student teaching experiences.

The STEM requirements for the MST major are summarized in Table 1. The actual level of content in each STEM component will vary by student, depending on their chosen specialization.

**Table 1** *STEM requirements for all MST majors*

Math	2 courses: Calculus-A, MAT105 (Content for Elementary) [and MTT202 (Math methods for Elementary)]
Science	3 courses [and MST202 (Science methods for Elementary)]
T&E	5 courses: Creative Design, Multimedia Design, Structures & Mech., Engineering Math & Integrated-STEM for Young Learners
M/S/T Electives	2 courses: Can be math, science or technology (in support of Specialization and/or endorsements)
Specialization	4 advanced courses determined by the chosen specialization. Specializations are (i) Math, (ii) biology, (iii) chemistry, (iv) Physics or (v) Technology

The level of math and science may be on-par with some teacher preparation programs. However, we suspect that the amount of math and science taken by MST majors is substantially higher. The calculus requirement is certainly uncommon. The level of T&E courses taken is also unique in an undergraduate teacher preparation program. By way of summary, math and science specialization MST majors take ~30% of the T&E course load of a K-12 Technology/Pre-engineering education major, while technology specialization students take approximately 60%. This is a high level of T&E content, especially considering that typical K-5 teacher preparation programs require no T&E content and no integrated-STEM educational content. Statistics available on the U.S. Department of Education’s Institute of Education Sciences (IES) website for National Center for Education Statistics (NCES) shows that an education major graduate in the USA in 1992-93 (the most recent year that data was available) completed an average number of 6.3, 10.4 and 0.3 semester credits in math, science and engineering, respectively. An MST major compares very well with these figures because they typically complete 16 credits in math, 16 credits in science and a minimum of 20 credits in T&E.

Brief descriptions of a few of the T&E courses are given below.

- (1) **Creative Design**: This course is typically taken in the freshman year and gives an introduction to basic materials, materials processing and design. Tools used in this class are typically available to the everyday elementary education teacher. The majority of this course consists of hands-on activities dealing with design and making. Many projects are team-based in one way or another. How materials, processes and aesthetic attributes effect design, and making, are covered in full experiential detail. The grade is primarily determined by performance on projected-based work. This course is also required by all first-year engineering students (mechanical, electrical/computer, civil and biomedical).

- (2) Engineering Math: Quantitative literacy is a substantial problem in the general populace and for the average elementary teacher. This class is a requisite for several other courses, ensuring a minimum base of math and physics. Even though calculus is required for the MST academic major, it is understood that calculus content will certainly not be required in K-5. Therefore, only minimal calculus is covered in this course. This course emphasizes effective problem-solving using basic mathematical skills and not on “memorizing the right equation for every problem.” Topics include calculating and graphing with Excel, units analysis, measurement & error/variability, probability/statistics (with applications in both engineering and education research), polar coordinates, the math of statics and dynamics (ballistics) with associated basic trigonometry, exponential functions (often in the context of financial or biological processes) and basic calculus processes with Excel. This course includes a variety of active “math labs” with the intent of making our future teachers capable and comfortable with applying mathematical concepts. The labs include: (i) Statistics of Olympics, (ii) Bungee Barbie (or Ken), (iii) Estimating/ calculating heights of local buildings and (iv) Assessing product reliability.
- (3) Structures & Mechanisms: Structural and mechanical devices give some of the more ancient examples of human technology in action, and continues to be important in our modern world. In this course students study mathematical aspects of materials properties (“materials science”) and how these properties effect the design of both structures and mechanisms. Basic machines are also covered. The design process is introduced as an academic subject and experienced through several labs and design/build projects. This course is a student’s first exposure to a variety of materials processing equipment. A common project is to design and build an automata toy, which integrates structures, mechanisms and sketching, as well as learning basic building processes.
- (4) Electronics: Electronics courses are not part of the MST core requirements. However, many MST majors take these courses to fulfill their elective requirement or their technology specialization requirements. Electronic devices dominate our modern world, so a good understanding of the basic science of electricity and electronics is valuable to a teacher that wants to relate the realities of the modern, and non-modern, world to their students. Three courses are offered: (i) Analog Electronics which includes the basic science of electricity, Ohms law, parallel & series circuits, capacitors, inductors, relays and basic semiconductor devices; (ii) Digital Electronics which covers binary numbers, Boolean algebra, basic state machines, common digital devices and microprocessor basics; and (iii) Controls & Robotics includes common analog and digital control circuits and microprocessor controlled systems (NXT Lego and C-Stamp). A major component of all electronics courses are hands-on lab experiences.
- (5) Integrated STEM for Young Learners: In this course students learn how STEM and non-STEM concepts can be integrated together, resulting in age appropriate activities (K-5, 6-8 and 9-12). Issues discussed include gender, context with Bloom’s taxonomy of learning and Gardner’s multiple modes of learning. Students typically design several lesson plans that include STEM components, possibly in cross-curricular modes with non-STEM content.

Upper level T&E courses are also taken routinely by MST students, primarily by technology specialization majors. These courses include Architecture & Civil Engineering, Mechanical Systems Design, Mechanics & Materials Laboratory, Facilities Design, Manufacturing Systems, Prototyping and Environmental/Biotechnology Systems.

In New Jersey, MST majors can also qualify for middle-school teaching endorsements in math and science, and often complete these endorsements. A middle school endorsement has two requirements: (i) completing 15 credits of appropriate course work in the discipline and (ii) passing the middle school content knowledge Praxis™ test. A K-12 endorsement in Technology Education is also possible for an MST major by completing at least 30 specified credits in technology and passing the Praxis™ technology education test.

### **Program Characterization**

A characterization of growth, gender and STEM content knowledge has been completed for MST students. Content knowledge is clearly an important building block for a teacher, and an obvious focal point when designing a teacher preparation program. Quantifying the level of content knowledge also allows comparisons to other populations or teacher preparation programs that offer varying levels of the STEM components. Additionally, a possible critique of any multidisciplinary program is that it may be too broad, negatively impacting the depth of content.

#### *Program Growth and gender effects:*

The MST program has experienced substantial growth. The MST program grew from 2 graduates in 2002 to 25 graduates in 2009. Current class sizes predict graduating class sizes of approximately 40 starting in Spring-2010. A high growth rate is a sign of a healthy program but also produces more STEM-trained and technologically literate teachers, an important and under-represented population.<sup>6</sup> Previous to the MST program, the eight non-STEM majors (Psychology, English, History, Sociology, Spanish, Woman & Gender Studies, Art & Music) comprised approximately 90% of the total K-5 teacher preparation program graduates, leaving historically 8-13% for the STEM majors of mathematics and biology.

Measured as a percentage of the total K-5 graduates at our institution, the MST program grew from 5% to ~30% from 2004 to 2010. For the most recent 4 years, math and biology graduates (the only other STEM K-5 majors chosen by students) have comprised approximately 6% and 2% of the total, respectively. This results in a total K-5 major STEM percentage at our institution of ~38%. This level of STEM-trained K-5 teachers is 4-to-5 times higher than the near-term average of ~8% for math and science. A comparison of this level of STEM-trained teachers to a National average would be interesting but the author could find no such statistics. Some states do not require a disciplinary major, and in states that do only the type of elementary certification appears to be tracked.

The fraction of MST graduates that are male is quite high. Over the last 6 years the male percentage has been a consistent 20-25%, which is approximately 5-fold higher than all other K-5 major averages at our institution and almost 3-fold higher than the 2001 national average for male K-5 teachers. [In 2001 the male percentage of K-5 teachers was ~9%, down from ~18% in 1981).<sup>7</sup> Investigations into the reasons for the higher male fraction have not been undertaken. However, it may be that males are attracted to the T&E components, a dominant

effect in engineering schools.

Another gender effect has not been investigated directly but is surely quite important. Not unlike most institutions offering K-5 teacher preparation programs, the MST graduates are mostly female (~75% for the MST major). However, there is a substantial difference; female MST graduates are well versed in all areas of STEM (STEM literate, if you will), which should result in MST graduates being effective role models for female K-5(8) students.<sup>8,9</sup>

### *(3) Measured M, S and T&E content knowledge*

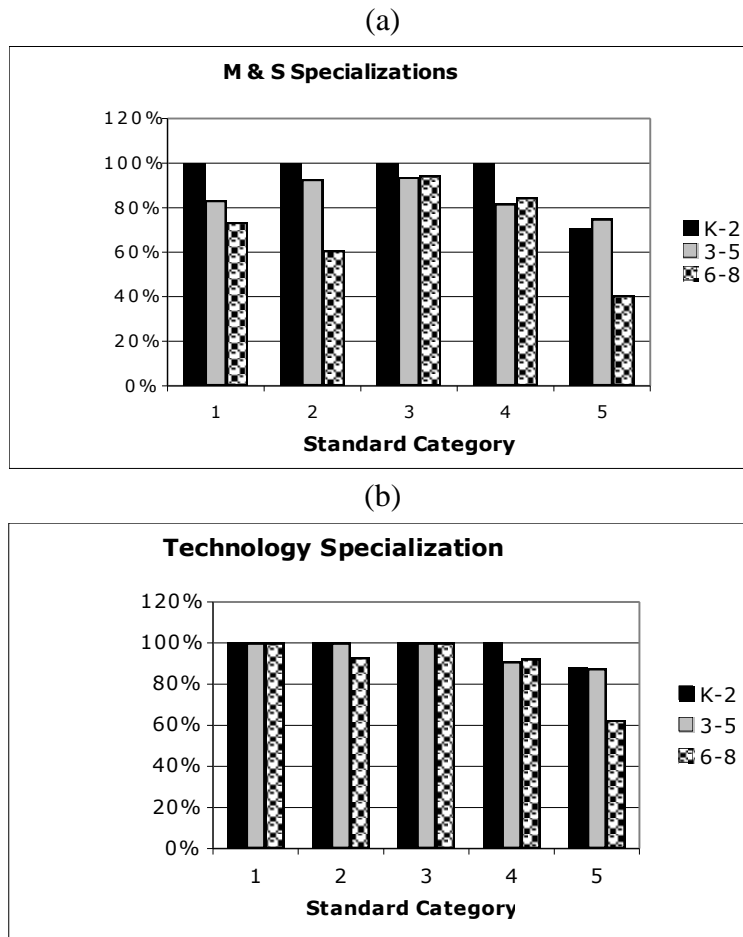
The depth of content knowledge is vital for both teacher effectiveness as well as attaining a certain level of technological literacy. The content knowledge level in science, math and technology & engineering for the MST majors has been measured and is summarized here.<sup>10</sup> These measurements indicate that competencies in all STEM areas are high while achieving performance equal to non-MST majors in very important non-STEM subjects. Specifically, MST majors scored statistically significantly higher than non-MST majors in national math and science Praxis<sup>TM</sup> tests while scoring equivalently in language arts and social studies. [The MST population scored 5.5% and 7.8% higher in math and science (for 95% confidence levels, math had p-value of 0.004 and science had p-value of 0.001).

Levels of anxiety in a subject matter can be a predictor of teaching effectiveness, and is also likely related to literacy levels. Previous work has also shown that low math anxiety levels are associated with lower levels of anxiety in science.<sup>11</sup> A similar result is expected with the MST majors, except in addition to low levels of math and science anxiety they should also have low levels of “T&E” anxiety, allowing them to comfortably execute active, hands-on and technologically-rich lesson plans for both STEM and non-STEM subjects. Measurements of math anxiety indicate that as MST majors progress through the math curriculum they attain a math anxiety level that is statistically the same as K-5 math majors at our institution. In contrast, the math anxiety of non-STEM K-5 majors remained 23% higher than the K-5 math major population after completing the same math curriculum. [This 23% difference was statistical significant ( $p=10^{-7}$  for 95% confidence levels).]

The content of the T&E course load taken by MST majors is perhaps best quantified by mapping it onto the Standards for Technological literacy (STL). The STL consists of twenty standards organized into five categories. Benchmarks are given for each of the twenty standards for four age groups; K-2, 3-5, 6-8 and 9-12. There are 101 benchmarks for grades K-5 and another 85 benchmarks for grades 6-8. Keeping in mind that there are two MST populations with differing T&E content, Figure 1 shows the results of the mapping for grades K-2, 3-5 and 6-8. This mapping indicates that, except for the 5<sup>th</sup> category of the STL, the math and science specializations have 80-100% coverage for grades K-5, while the technology specialization has 90-100% coverage. The 5<sup>th</sup> category of standards includes benchmarks for 7 specific technologies. The breadth of the MST program does not allow coverage of all of these specific technologies. In the 5<sup>th</sup> category, the MST program coverage is at the 60-70% level for math and science specializations, and above 80% for technology specializations. It should be noted that specific knowledge is not necessary in all 7 of these technology areas to be technologically literate. Given that technology is changing



so quickly it is more important for a teacher to have a desire for continuous learning of technological material.



**Figure 1** A mapping of the MST T&E curriculum onto Standards for Technological Literacy (STL) for the two specialization groups of (a) math or science and (b) technology.

Additionally, an analysis of grades for the core and upper level T&E courses indicates that, compared head-to-head in the exact same classes, the grades earned by MST majors are consistently equal to, or more often, higher than the Technology/Pre-engineering students. This result also held true for the more hands-on lab courses. So, MST majors are not simply “surviving” the T&E courses but are performing quite well, even compared against a Technology/Pre-engineering population that consistently performs well above average on the national Praxis™ technology education exam. An external, and more direct, measure of technological literacy of the MST students is possible because a few of the technology specialization students have recently completed the technology education Praxis™ exam. Scores on this exam for three MST majors were between 630-640, scores within the national average performance range of ~620-680.

Collectively, these measurements of math, science and T&E content knowledge indicate that the breadth of the MST program did not adversely compromise the depth of STEM or non-

STEM skills, resulting in graduates with a powerful mix of new skills and capabilities.

*(4) Informal learning environment*

We think a significant level of T&E content is learned by the MST population through an “informal” environment established by our department. The informal learning environment can be divided into two categories: (i) professional activities and (ii) diverse coexisting programs/populations.

(i) Professional activities:

An important source of STEM knowledge and experiences for MST majors comes from a large amount of professional activities occurring outside of courses, and therefore are hard to quantify by looking at curriculum. The Department has a very active professional calendar which includes: (a) hosting an annual all-day professional conference with formal talks and workshops (typical attendance is ~80 professionals), (b) hosting bi-monthly professional workshops, (c) annual trips to the eastern regional Technology Educators Collegiate Association (TECA) student conference/competition, (d) hosting an annual robotics competition and workshop, (e) hosting the annual Technology Student Association (TSA) state-wide competitions, (f) hosting ~80 local high school students for an annual “Junior/Senior Design Challenge” as well as numerous activities organized by our institution’s technology student organization. Collectively, these events give MST majors a level of professional STEM experiences that is a substantial addition compared to typical K-5 programs.

(ii) Diverse coexisting programs/populations

In our School there are two important populations that interact in significant ways with the MST population; (i) the Engineering School students and staff and the (ii) Technology/Pre-engineering education majors. Being housed in the School of Engineering certainly gives a strong technology focus to the environment. By example, the School of Engineering has recently been considering additions to our facility. This is a very current and real architectural design problem, one that became a formal modeling assignment for our education majors. The resulting models were not only good educational projects but also helped the faculty consider certain attributes.

The Technology/Pre-engineering education majors interact the most with MST majors. The MST and Technology/Pre-engineering programs have had numerous positive impacts on each other. The Technology/Pre-engineering majors are primarily male while the MST majors are primarily female, and as the MST population has grown these two populations have substantially increased their out-of-class interactions for both coursework as well as social interactions. By example, in Fall-2009 our Department’s attendance at the eastern regional TECA student conference, which has as a focus numerous technology competitions, was over 40 students, which is approximately 2-times larger than in the previous ~6 years. Increased involvement has also occurred for several other professional events. Increased interaction at technology-focused events like this surely increases the technological literacy for both populations.

The characterization of the STEM capabilities of the MST students, briefly reviewed above,

indicate that MST program graduates should be highly technologically literate compared to non-STEM K-5 majors, and likely compared to the adult population in general. Hence, any technological literacy instrument should delineate the MST population from other non-STEM K-5 teacher populations. The context set previously in this paper for technology was the STL. However, it might be useful to put the skills learned by MST graduates in context to the framework defined in the technological literacy measurement efforts underway by the National Assessment of Educational Progress (NAEP) and WestEd.<sup>12,13</sup>

The technological literacy framework set forth by the NAEP effort consists of three “areas” and three “practices.” The three areas are: (i) Technology and Society, (ii) Design and Systems and (iii) Information & Communications Technology. The three practices are: (i) Identifying & Applying Principles, (ii) Using Processes to Solve Problems & Achieve Goals and (iii) Communicating & Collaborating. The three “areas” of technological literacy can be thought of as the content knowledge and basic skills that are expected of technologically literate persons, whereas the “practices” are the cognitive processes enabled with technologically literate persons. The curriculum an MST student receives closely aligns with the curriculum set forth in all technology/pre-engineering programs in the USA and certainly overlaps substantially with both the content knowledge as well as the cognitive expectations set forth in the proposed framework. Therefore, we would expect the MST graduates to exhibit high levels of technological literacy in NAEP’s instrument.

To our knowledge, the MST program is unique in the USA. We are not aware of another K-5 undergraduate teacher preparation program that requires extensive T&E content. There are several undergraduate institutions that offer math and science combinations and some that offer limited T&E. There are a few graduate education programs that offer STEM content. The MST population, having deep STEM skills (especially T&E), offer some unique and valuable possibilities for any newly developed technological literacy instrument.

- (1) The MST population would serve as an effective sub-population in pilot runs of the instrument, serving as a baseline for K-5, and perhaps 6-8 teachers. Such measurements could take place for graduating seniors and/or graduates of the program. Technology specialization MST students/graduates, having completed an even more extensive curriculum in technology, could also be tracked to determine if this subgroup would produce useful comparisons. Similarly, MST graduates could also be used as a continuing calibration for the instrument.
- (2) If research shows that MST graduates substantially effect the technological literacy (really the STEM-literacy) of their K-5(8) students then clearly a sub-population made up of K-5(8) students of MST graduates would be a useful for NAEP to use as a baseline or for ongoing calibration. In this regard another interesting K-5(8) student population would be students that are in neighboring classrooms, neighboring schools and nearby schools but out-of-district. Such comparisons may determine if the MST graduates are impacting their surroundings.
- (3) Another interesting population would be TCNJ K-5 non-MST graduate populations that historically have higher levels of math anxiety. On the assumption that the “high math anxiety” K-5 majors at TCNJ would also exhibit low levels of STEM literacy then such a population would be interesting simply as a direct comparison to TCNJ

MST graduates. For example, TCNJ School of Education students in general have relatively high Scholastic Aptitude Test (SAT) scores. So, one would like to determine any influences of existing aptitudes/experiences on technological literacy.

- (4) Unrelated to the MST program, certainly K-12 (i.e. 6-12) technology education graduates from numerous schools would serve as an obvious choice for baseline populations for the 9-12 teacher population since their curriculum overlaps NAEP's framework.
- (5) Perhaps it is too obvious to mention but a technological literacy instrument, if effective, could be used to better quantify technological literacy standards, and perhaps STEM literacy standards, for K-12 students and K-12 teachers. For example, if correlations are observed between literate teachers and literate students as well as these students' academic performance in K-12 and 13-16<sup>+</sup>, then standards should be able to be better quantified, or at least verified.
- (6) An instrument for T&E anxiety might be easier to define, and implement than a technological literacy instrument. A T&E anxiety instrument might be useful for teacher preparation programs, just as math and science anxiety instruments are useful. Math students with high math anxiety often have low math literacy, although there are certainly exceptions. However, for teacher preparation programs a teacher candidate that has high math literacy but still possesses high math anxiety is still at a disadvantage in teaching math. Similarly, a measure of T&E anxiety could prove useful for teacher preparation programs.

### **Future Research Directions**

Research related to the MST program and its graduates could be divided into three categories: (i) "internal" studies of teaching qualities/capabilities of MST students/graduates, (ii) "external" studies of the effects of MST graduates on their environment (fellow teachers, administrators, policy and certainly K-5(8) students themselves) and (iii) institutional/governmental issues for implementing MST-like programs.

The only measurements completed so far on the MST program are the "internal" studies briefly reviewed earlier in this paper. Internal studies offer valuable information and are also a relatively time- and cost-efficient method of quantifying likely benefits to K-5(8) students. For example, previous research results indicate that low math anxiety is a good indicator of effective math teaching. Internal studies of MST students and their capabilities/qualities can be completed in timeframes measured in weeks or months, as opposed to longitudinal studies of K-5 students that can take years. The ultimate, and direct, measure would certainly be to complete external measures of the effects of MST-trained teachers on K-5(8) students, perhaps through test scores and/or interest-levels in STEM fields. Lastly, both institutional and governmental structures and policies can be limiting. For example, when a Department or School wish to implement an MST or MST-like program, there still may be institutional or government barriers. By example, in New Jersey a disciplinary major is required of K-5 education majors, which administratively allows a quick definition of a new, and in this case, multidisciplinary major. In States that do not have a disciplinary major requirement how could curricular requirements in all areas of STEM be best accomplished? Questions also arise about how much and what type of T&E capability would be optimum, and how

institutions without technology education departments could offer T&E content. Investigations and research into innovative methods around these barriers should prove fruitful, and have obvious implications on technological literacy measurements, STEM literacy measurements and T&E standards in K-12 (and teacher preparation programs).

A review of some anecdotal data on the effect of MST graduates and some future research topics surrounding the MST program are outlined below.

(1) Anecdotal Data:

Obvious questions about the MST program arise. What impact are MST graduates having in schools? Are MST graduates more effective at teaching STEM and/or non-STEM concepts? Are the K-5 students of MST graduates performing better at classic subjects? Are the K-5 students of MST graduates more technologically literate or have lower T&E anxiety? Compared to other new teacher populations do MST graduates adjust quicker in their new roles as teachers? There are a variety of anecdotal data that indicate that MST graduates are having a substantial impact in their new teaching environments.

- a) MST graduates have very close to a 100% hire rate, with some offers coming at midyear of their senior year.
- b) Due to their past experiences with MST graduates, there is one principle that calls our department whenever they have K-5 openings, looking specifically for MST graduates. A similar example occurred recently. Leadership of our state technology organization (New Jersey Technology Educators Association) volunteered to run a workshop series for the New Jersey Principles & Supervisors Association on 21<sup>st</sup> century skills, with this session focusing on innovation in the classroom. There were approximately 12 participants. In an “Introductions” session a discussion was initiated about what attendees thought were key challenges in their schools. Several attendees expressed surprise that some of their newer K-5 teachers (teachers from non-TCNJ institutions) were having unexpected difficulties with technology in the classroom, an issue they might have expected from older teachers. An Assistant Superintendent, upon hearing these comments, stated that they have been hiring MST majors and that they were extremely pleased with their classroom capabilities.
- c) A New Jersey government official, well after the establishment of the program, stated that she has heard many very good comments about the MST program.
- d) Conversations with ~10 MST students just after or during their capstone student teaching experience indicate that a substantial amount of S and T&E is getting integrated into their classrooms via lesson plans they are designing. A few years ago an MST student teacher was allowed to implement science lessons to the class, even though the school policy was to not do science but, rather to focus on the three “R’s.” The teacher was clearly taking a risk in letting the student teacher implement such lessons, but felt comfortable enough with the student to support her. Another MST student shared her recent student teaching experiences on designing a lesson around the story Owen by Kevin Henkes. The story is about a young (boy) mouse named Owen who, like many young children, is very attached to his blanket. However, when it came time for him to start school his mother would not let him bring his blanket to school. However, his mother does tell Owen that she can make something

out of the blanket in which he can bring to school. The MST student teacher designed an exceptionally good lesson with a part of the lesson consisting of giving a sheet of felt (a “blanket”) to each student and asking them to design and make something that Owen could bring to school. The lesson had clear expectations/ constraints and required the use of hands-on tools and processes. The student teacher also put together student materials that introduced “engineering” terms and gave materials that encouraged a “design process” to occur. Several interesting objects were made including a backpack and a folder. Discussions followed with the students about how these objects would be used by Owen in school. This lesson was centered on Reading, one of the three “R’s,” but certainly integrated T&E in a very intimate and direct manner. The MST students routinely design outstanding cross-curricular lessons, often integrating T&E content.

(2) “Internal” Research:

- a) Survey student teachers and their experience and lesson plans.
- b) Technological literacy, T&E anxiety & self-efficacy of teacher candidates (MST vs. non-MST populations).
- c) STEM affect of teacher candidates (MST vs. non-MST populations).
- d) Lesson plan design effectiveness w.r.t. STEM, but especially T&E content (MST vs. non-MST populations).

(3) “External” Research:

- a) Locate and conduct surveys of current MST graduates to define basic population characteristics. What subjects are they teaching and at what level (K-5 is very different than 6-8). Are graduates integrating T&E content? Are graduates involved in defining STEM-oriented curriculum? Extend survey to fellow teachers, supervisors and administrators.
- b) Longitudinal studies of the effects of MST teachers on student outcomes (STEM capabilities and STEM interest) and fellow teachers, administrators and curriculum.
- c) Technological literacy, T&E anxiety and self-efficacy.
- d) Characterize the effectiveness of M-S programs compared to MST programs (on learning or integrating STEM content)
- e) Affect towards STEM in students, fellow teachers. (MST vs. non-MST graduates).

(4) Institutional/governmental barriers:

- a) Investigate potentially effective methods of initiating MST programs at other institutions. This may involve categorizing institution types by whether or not they have technology departments and/or engineering schools. T&E content learned via online methods may be possible for institutions without T&E teaching capabilities.

- b) Investigate T&E literacy standards in various states for K-5, and how these are being met by teacher preparation programs and K-5 schools.

### **Summary**

The representation of deeply STEM-trained teachers is low in K-5. The level of T&E skills and knowledge in K-5 teachers is even lower. Therefore, programs that can substantially increase the number of STEM-trained K-5 teachers should have a beneficial impact on K-5(8) student outcomes in content knowledge and STEM literacy. The K-5(8) school years are incredibly important for learning basic skills and affect towards subjects, as well as problem-solving skills that are useful later in school and later in life. Increasing the STEM literacy of K-5(8) teachers should result in higher skills and interest in STEM subjects by the K-5(8) students, but perhaps even more importantly lead to a higher STEM literate population, enabling effective dialog and decision-making on a host of high-tech issues and problems. The MST program described in this paper is such a program. The MST program graduates highly STEM-literate (all four elements) K-5(8) teachers, and has grown rapidly in the last few years. This year, MST majors (one of 11 possible K-5 majors) will comprise approximately 30% of all of the K-5 graduates. To our knowledge this undergraduate MST program is the only one in the USA that requires such deep levels of T&E (along with M & S). The growth of the program indicates that it is more attractive to students. If this program could be implemented at other institutions then even a larger impact would result. Certainly, more data on the impact of MST graduates on their K-5(8) students would be useful in extending the MST model to other institutions, and such research has been started.

The curriculum that MST majors take, being comprised of the T&E courses of a K-12 technology/pre-engineering teacher preparation program, is specifically designed to graduate technologically literate future teachers. Hence, even without research on the impact on K-5(8) students, the MST program is already producing highly technologically literate future K-5(8) teachers, teachers that are getting hired at a high rate and integrating T&E into their student teaching experiences. Being a unique technologically literate population, the MST graduates could be useful for future technology literacy instruments to exploit for baseline and calibration purposes, as well as for setting research-based technological literacy standards for K-5(8) students and K-5(8) teachers. But also, if the goal and benefit is to produce more technologically literate K-5(8) teachers, or perhaps worded more accurately more “STEM-literate” K-5(8) teachers then the MST program is already accomplishing this.

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