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Teaching interest: Dr. Van der Sandt’s teaching covers both pure mathematics and mathematics education. Pure mathematics courses include Calculus and Applied Liberal Art Mathematics. Mathematics education courses include both content courses and methodology courses specifically designed for education students: e.g. Mathematical Structures and Algorithms for Educators; Perspectives on the Development of Mathematics; Teaching Mathematics in the Early Childhood and the Elementary Classroom; Patterns, Functions, and Algebra for Middle School Teachers and regularly visits schools to observe senior mathematics education majors during their student teaching.

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Math anxiety and math teaching beliefs of a K-5 integrated-STEM major compared to other teacher preparation majors

Abstract:
In this work math anxiety, math teaching self-efficacy (SE) and math outcomes expectancy (OE) are measured on a large sample of K-5 teacher candidates, where the teacher candidates vary among several STEM and non-STEM majors. One of the STEM-oriented majors, referred to as the Math/Science/Technology (MST) major is an integrated-STEM major that requires substantial content in all four elements of STEM, as well as interdisciplinary components that integrate STEM, and non-STEM, subject matter. A hypothesis that the MST major would exhibit anxiety, self-efficacy and teaching outcome expectation levels that are on-par with the population of K-5 math majors was found to be true, but only after achieving substantial improvements through the progression of their curriculum.

Introduction:
A recent update on the National Academies report “Rise above the Gathering Storm” indicated that K-12 students in the USA ranked 48th in the world in terms of math and science capability.[1] Achieving an effective K-12 teacher population is critical to overcoming this problem, and was the first recommendation of the original report in 2007. Having low anxiety, high self-efficacy and high outcomes expectancy in a subject is important to becoming an effective teacher in that subject. The K-8 grade range is an important grade range for students in Science, Technology, Engineering and Math (STEM) subjects because after this grade range both affect and capabilities are largely determined.

Studies have shown that teachers with high levels of math anxiety tend to pass on this anxiety of mathematics onto their students.[2] The vast majority of elementary education majors are female and exhibit the highest level of math anxiety of any major.[3] Beilock, Gunderson, Ramirez and Levine found that teachers with high math anxiety specifically affect girls’ math achievement by influencing girls’ gender-related beliefs about who is good in math.[4] Additionally, Teague and Austin-Martin stated that a teachers' attitude toward mathematics may affect not only the students' values and attitudes toward mathematics but also that these attitudes may impact the effectiveness of the teaching itself.[5] Teachers with low teaching self-efficacy tend to avoid student-centered and inquiry-based teaching methods and instead use lecture and teacher-directed learning. This could result in an endless cycle of mathematics anxiety, since the use of inquiry-based teaching methods has been shown to reduce math anxiety in children.

In this paper we present the results of ~1000 measurements of math anxiety, math teaching self-efficacy (SE) and math teaching outcomes expectancy (OE) of ~250 K-5 teacher candidates. In our State, New Jersey, a second disciplinary major is required in addition to the
teacher candidate’s education major (Elementary, Early Childhood, Special Ed. or Deaf & Hard of Hearing). There are 11 possible K-5 disciplinary majors at our institution. In this work analyses of math anxiety, SE and OE are broken down by specific disciplinary major, resulting in a comprehensive assessment of the relative preparedness of different majors to teach math, and by inference science since literature also suggests that low math anxiety is correlated with low science anxiety.[6] One of the K-5 majors, referred to as the Math/Science/Technology (MST) major, is an integrated-STEM major that requires substantial content in all four elements of STEM, as well as interdisciplinary components that integrate STEM, and non-STEM, subject matter. Upon graduation, most MST education majors also complete endorsements for middle school math or science (and often both). Detailed descriptions of the MST major were previously reported.[7,8] Briefly stated, an MST K-5 major is required to take a minimum of 2 math courses (and one math methods course), 3 science courses (and one science methods course) and 5 technology & engineering (T&E) courses.

Our hypothesis is that, even though K-5 MST education majors take less math and science coursework compared to K-5 Math majors that, due to the level of math content and the integrated nature of their major, will attain math anxiety and math teaching efficacy beliefs levels that are comparable to K-5 math disciplinary majors.

**Theoretical Framework**

Anxiety and teaching self-efficacy, in the context of teaching math, are two of the constructs central to the proposed study. Math anxiety is the result of a student's negative or embarrassing experiences with math or a math teacher in previous years. These experiences can leave a student with the belief that they are deficient in math. Math anxiety can therefore be defined as intense emotions of anxiety about the ability to understand and do math.

As stated in Trujillo,[9] there is a particular concern in the case of elementary teachers, because it has been reported that a disproportionately large percentage of this population experience significant levels of mathematics anxiety.[9,10] Additionally, a significantly larger percent of pre-service teachers report experiencing higher levels of math anxiety than other undergraduate university students.[3,11] Frank found that many future teachers shared many of the math beliefs held by students with severe mathematics anxiety enrolled in math anxiety clinics.[12] Kelly and Tomhave have discovered that prospective elementary school teachers scored higher on anxiety rating scales than any other group in the large group of college freshmen they tested.[13] The Texas State University Counseling Center reported that incidences of math anxiety have risen significantly over the last decade, with many students choosing their college major on the basis of how little math is required.[14] The mathematics requirements for elementary education majors are typically minimal and the population consist mostly of female teacher candidates that exhibit the highest level of math anxiety. The anxiety levels of these future teachers will have negative consequences for their students’ math achievement.[15]
Beliefs influence teacher behavior and decision-making.[16] Self-efficacy, as defined by Bandura’s theory of social learning, is the personal perception of one’s capabilities to produce actions, and outcome expectations involving beliefs about the anticipated outcomes of those actions.[17] Self-efficacy in the context of teaching has been defined as a two dimensional construct.[18] Personal teaching efficacy is a teacher’s expectation about his/her capabilities to teach effectively, while teaching outcome expectancy is the belief that effective teaching will have a positive effect on student learning, regardless of external factors such as home environment, family background, and parental influences.[19]

Schunk affirms this theory, and research suggests that efficacy beliefs are domain specific, so it is meaningful to speak of self-efficacy of the teaching of mathematics.[20] Individuals differ in their self-efficacy for teaching as a function of their prior experiences doing the same or similar activities. Thus, a teacher will form math self-efficacy beliefs through all previous math experiences, both teaching and non-teaching, similar to the development of math anxiety. Prior success in math will lead to higher levels of self-efficacy, while negative experiences in mathematics may have a negative effect on self-efficacy and create anxiety with respect to math.

Gibson and Dembo state “…teachers who believe student learning can be influenced by effective teaching (outcome expectancy beliefs) and who also have confidence in their own teaching abilities (self-efficacy beliefs) should persist longer, provide a greater academic focus in the classroom, and exhibit different types of feedback than teachers who have lower expectations concerning their ability to influence student learning.” [21, p.570]

**Data Sources**

Two surveys were used to determine our pre-service teacher's level of math anxiety and math teaching self-efficacy. The Revised-Mathematics Anxiety Survey (R-MANX) was used to measure math anxiety levels. The R-MANX survey contains 30 items in which students respond on a scale from 1 (no anxiety) to 5 (high anxiety).[6,22] Possible scores range from 30-150 where higher scores indicate higher math anxiety. Items asked the student to define their level of math anxiety when dealing with daily situations and their own coursework. Seven of the R-MANX questions are reverse-coded, requiring arithmetic corrections to obtain the final R-MANX score.

The Mathematics Teaching Efficacy Belief Instrument (MTEBI- Mathematics Pre-service) was used to determine the pre-service teachers’ beliefs in their ability to teach math. The MTEBI consists of 21 items. Both the construct validity and the reliability of the MTEBI have previously been examined by Enochs, Smith and Huinker in 2000.[18] Using confirmatory factor analysis, they established support for a two factor model consisting of 13 self-efficacy
(SE) items and 8 outcome expectancy (OE) items loading on two independent factors. Eight of the 13 SE questions are reverse-coded requiring arithmetic corrections to obtain the final SE score. The minimum and maximum scores for the SE instrument are 13 & 65, respectively. The minimum and maximum scores for the OE instrument are 8 & 40, respectively. For SE and OE measurements higher scores represent higher (better) efficacy levels. Previous reliability analyses produced internal consistency estimates (Cronbach's alpha) of 0.88 for the SE scale and 0.77 for the OE scale.[18]

Methods
Participants in this study were pre-service K-5 education majors (Elementary, Early Childhood, Special Ed. or Deaf & Hard of Hearing) with a variety of required second disciplinary majors. All students were typically in their freshmen or sophomore year at The College of New Jersey (TCNJ). The students had not yet completed their student teaching requirement. All pre-service education majors were asked to voluntarily complete the R-MANX and MTEBI surveys at the beginning and end of their compulsory mathematics content course (MAT105) and their compulsory mathematics methodology course (MTT202). The course MTT202 is taken after MAT105. This yields a total of four measurement points, allowing for three pre-post pairings (one for each compulsory course and one pre-post pairing between Pre105 and Post202). Mathematics majors are not required to take MAT105.

In MAT105 (“Math Structures & Algorithms for Educators-I”) students are engaged in a thorough development of patterns, numeration, mathematical systems, real numbers, and number theory – thus developing a deep understanding of the processes and algorithms found in elementary mathematics and discover purposes beneath the symbols and techniques. Physical materials and models are used to explore fundamental concepts in each area. Students are required to reason mathematically, solve problems, and communicate mathematics effectively at different levels of formality, using a variety of representations of mathematical concepts and procedures. The MTT202 course is a math methods course that examines the early childhood, elementary, and middle school mathematics curricula, how children learn mathematics, methods and strategies appropriate for teaching the many topics in mathematics. Students are introduced to national and state standards for preK-8 mathematics, and learn how to teach according to these standards. Topics include the use of manipulatives and technology in teaching mathematics, learning theories, adaptations for diverse learners, and the investigation of standards-based curricula.

In New Jersey a second disciplinary major is required of all education majors. One of the K-5 majors is the MST education major. Currently, the MST major alone comprises ~27% of the total K-5 teacher candidates, making it the largest single K-5 major. To attain more depth in a subject area, MST majors are also required to pick one of three specializations [Math, Science
or Technology & Engineering (T&E)], each of which requires more coursework in that particular subject area.

**Results**

This section provides the results of our analyses of math anxiety (R-MANX) and teaching beliefs (SE and OE) segmented by major. There are 11 possible K-5 disciplinary majors at our institution: Art (AR), Biology (BIO), English (ENG), History (HIS), Math (MAT), Music (MU), Psychology (PSY), Sociology (SO), Spanish (SPA), Woman & Gender Studies (WG) and MST. The population of Biology majors was quite small so is ignored in this study. The 8 non-STEM majors currently make up approximately 65% of the total population, leaving approximately 35% for the three STEM-oriented majors of MAT, MST and BIO. The required math and science content for the 8 non-STEM majors is MAT105 & MTT202 (previously described), MAT106 (“Math Structures & Algorithms for Educators-II”), any science course and a science methods course. The PSY major has additional required math content: statistical methods provided “in context” within the psychology department, including a 1-semester research project. In size, the Psychology, English and History majors dominate the non-STEM majors. In this study, the majors of Art and Music, as well as the majors of Sociology and Woman & Gender Studies, are combined to create larger populations. The statistical assumptions in this work were that samples are simple random sampled and that distributions are normally distributed. Populations were used only if the distributions were reasonably normal.

Two methods of data analyses were completed. In the first method the results of “paired” analyses are completed to assess primarily the effects of each of the compulsory math education courses (MAT105 and MTT202). The second analysis was an “unpaired” analysis of the data. Unpaired analyses can be used to compare majors but in a manner that allows significantly larger population sizes.

I. Course Analyses (paired)

In this section the effects of the two math courses (MAT105 & MTT202) are analyzed by using a paired analysis of data taken for math anxiety (R-MANX), math teaching self-efficacy (SE) and math teaching outcomes expectancy (OE). This analysis counts only those teacher candidates that successfully completed surveys both before and after a course so therefore assess primarily the effects of that course.

A) Math Anxiety (R-MANX)

For MAT105 there were 7 possible populations of majors; five of these populations showed decreases in the mean anxiety while the SPA showed a very small increase (+0.7%). For MAT202 all eight major populations showed decreases in the mean anxiety. Table 1 presents the results of the paired comparative t-tests of R-MANX, organized by disciplinary major...
population, for three cases: (i) Pre105:Pos105, (ii) Pre202:Pos202 and (iii) Pre105:Pos202. Table 1 shows population size (N), p-value (1-tail) and mean differences in anxiety. The math major population is not assessed relative to MAT105 since this course is not required for K-5 math majors. For MAT105 four major populations exhibited statistically significant decreases in anxiety. The MST and SO/WG majors showed the largest decreases in anxiety, 6.4 and 4.8, respectively. Spanish and History majors showed no significant decreases in anxiety after MAT105.

For MAT202 significant decreases in anxiety were observed in 5 of the 8 possible majors, leaving the 3 populations of Math, MST and Psychology without significant reductions in anxiety. For the paired comparison between Pre105 and Pos202 the decrease in population sizes only allowed an analysis of 4 major populations. Of these four majors, three showed significant decreases in anxiety (English, MST and Psychology). The two largest observed paired decreases in anxiety between Pre105 and Pos202 were in the majors of MST and Psychology. The MST and Psychology majors are also the only two majors that exhibit a higher decrease in anxiety in the Pre105-Pos202 pairing than would be expected by accounting for the anxiety decreases measured for the two individual course pairings (Pre105-Pos105 and Pre202-Pos202). For example, for the MST major the individual courses would predict a decrease in anxiety of 6.5 units (4.8 + 1.7), while the Pre105-Pos202 pairing actually yields a 3.1 unit larger decrease in anxiety of 9.6. This 3.1 unit “additional” decrease in anxiety represents ~32% of the total decrease. The Psychology major exhibits a 1.9 unit “additional” decrease in anxiety which represents ~30% of their total decrease. This behavior is also consistent with the unpaired decreases in anxiety presented in the next “unpaired” section.

Table 1  Population sizes, p-values (1-tail) and mean differences for RMANX scores for three comparisons: (i) Pre105:Pos105, (ii) Pre202:Pos202 and (iii) Pre105:Pos202. [Statistical significance to the 0.1 level are denoted by grey shading, while statistical significance to the 0.05 level are denoted by an asterisk.]

<table>
<thead>
<tr>
<th>Major</th>
<th>PrPo105</th>
<th>PrPo202</th>
<th>Pr105Po202</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N  p  Xd</td>
<td>N  p  Xd</td>
<td>N  p  Xd</td>
</tr>
<tr>
<td>AR/MU</td>
<td>x x x</td>
<td>10 0.035* -6.6</td>
<td>x x x</td>
</tr>
<tr>
<td>ENG</td>
<td>50 0.097 -2.6</td>
<td>36 0.024* -3.2</td>
<td>26 0.061 -4.1</td>
</tr>
<tr>
<td>HIS</td>
<td>27 0.304 -1.3</td>
<td>13 0.044* -4.8</td>
<td>x x x</td>
</tr>
<tr>
<td>MAT</td>
<td>na na na</td>
<td>14 0.284 -0.8</td>
<td>na na na</td>
</tr>
<tr>
<td>MST</td>
<td>17 0.089 -4.8</td>
<td>45 0.125 -1.7</td>
<td>15 0.020* -9.6</td>
</tr>
<tr>
<td>PSY</td>
<td>47 0.023* -3.7</td>
<td>51 0.238 -0.8</td>
<td>20 0.001* -6.4</td>
</tr>
<tr>
<td>SO/WG</td>
<td>30 0.012* -6.4</td>
<td>29 0.080 -2.5</td>
<td>12 0.131 -4.0</td>
</tr>
<tr>
<td>SPA</td>
<td>15 0.443 +0.5</td>
<td>13 0.066 -4.2</td>
<td>x x x</td>
</tr>
</tbody>
</table>

B) Self-Efficacy (SE)

For MAT105 there were 6 populations with sufficient sample sizes; five of these six populations showed increases in the mean SE. The seventh major, Spanish, showed a very
small decrease in mean SE. For MAT202 all eight majors showed increases in the mean SE. Table 2 presents the results of a series of paired comparative t-tests of SE, organized by disciplinary major, for three cases: (i) Pre105:Pos105, (ii) Pre202:Pos202 and (iii) Pre105:Pos202. Table 2 shows population size (N), p-value (1-tail) and mean differences. The math major population is not assessed relative to MAT105 since this course is not required for K-5 math majors.

For course MAT105 significant decreases in SE were observed in 4 of the majors, leaving the two major populations of MST and Spanish without significant increases in SE. For course MTT202 significant increases in SE were observed in 7 majors. For the paired comparison between Pre105 and Pos202 the decrease in population sizes only allowed an analysis of 4 major populations, and SE significantly increased in all of these majors. The largest observed paired increases in SE between Pre105 and Pos202 were again the MST and Psychology majors. The MST major is also the only major that exhibits a higher increase in SE in the Pre105-Pos202 pairing than would be expected by accounting for the SE increases measured for two individual course pairings (Pre105-Pos105 and Pre202-Pos202). For example, for the MST major the individual courses would predict an increase in SE of 3.3 units (1.5 + 1.8), while the Pre105-Pos202 pairing actually yields a 2.3 unit higher SE increase of 5.6. This 2.3 unit “additional” increase in SE represents ~41% of the total increase in SE. This behavior is also consistent with the unpaired increases in SE presented in the next “unpaired” section.

Table 2  Population sizes, p-values(1-tail) and mean differences for SE scores for three comparisons: (i) Pre105:Pos105, (ii) Pre202:Pos202 and (iii) Pre105:Pos202. [Statistical significance to the 0.1 level are denoted by grey shading, while statistical significance to the 0.05 level are denoted by an asterisk.]

<table>
<thead>
<tr>
<th>Major</th>
<th>PrPo105</th>
<th>PrPo202</th>
<th>Pr105Po202</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR/MU</td>
<td>x x x</td>
<td>x x x</td>
<td>x x x x</td>
</tr>
<tr>
<td>ENG</td>
<td>52 0.014* 2.1</td>
<td>34 0.005* 2.6</td>
<td>32 0.009* 3.0</td>
</tr>
<tr>
<td>HIS</td>
<td>20 0.045* 2.6</td>
<td>14 0.035* 4.1</td>
<td>x x x x</td>
</tr>
<tr>
<td>MAT</td>
<td>na na na</td>
<td>15 0.001* 3.5</td>
<td>na na na</td>
</tr>
<tr>
<td>MST</td>
<td>17 0.194 1.5</td>
<td>39 0.03* 1.8</td>
<td>15 0.008* 5.6</td>
</tr>
<tr>
<td>PSY</td>
<td>47 0.000* 3.5</td>
<td>52 0.000* 3.9</td>
<td>20 0.001* 4.9</td>
</tr>
<tr>
<td>SO/WG</td>
<td>31 0.057 2.0</td>
<td>29 0.095 1.2</td>
<td>12 0.064 1.5</td>
</tr>
<tr>
<td>SPA</td>
<td>15 0.302 -0.9</td>
<td>13 0.038* 1.4</td>
<td>x x x x</td>
</tr>
</tbody>
</table>

C) Outcomes Expectancy (OE)

Presented in Table 3 are the results of a series of paired comparative t-tests of OE, organized by disciplinary major, for three cases: (i) Pre105:Pos105, (ii) Pre202:Pos202 and (iii) Pre105:Pos202. Table 3 shows population size (N), p-value (1-tail) and mean differences. Counting all possible pairings only two showed significant changes, and were increases in OE. The two occurrences of increased OE occurred in course MTT202 for the majors of History
and MST. T-test analyses verified that there were no significant differences on OE between all populations of majors.

### Table 3

Population sizes, p-values(1-tail) and mean differences for OE scores for three comparisons: (i) Pre105:Pos105, (ii) Pre202:Pos202 and (iii) Pre105:Pos202. [Statistical significance to the 0.1 level are denoted by grey shading, while statistical significance to the 0.05 level are denoted by an asterisk.]

<table>
<thead>
<tr>
<th>OE:</th>
<th>PrPo105 N</th>
<th>p</th>
<th>Xd</th>
<th>PrPo202 N</th>
<th>p</th>
<th>Xd</th>
<th>Pr105Po202 N</th>
<th>p</th>
<th>Xd</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR/MU</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>8</td>
<td>0.2</td>
<td>-1.8</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>ENG</td>
<td>52</td>
<td>0.2</td>
<td>-0.8</td>
<td>34</td>
<td>0.483</td>
<td>-0.4</td>
<td>32</td>
<td>0.745</td>
<td>0.2</td>
</tr>
<tr>
<td>HIS</td>
<td>20</td>
<td>0.793</td>
<td>0.2</td>
<td>14</td>
<td>0.008*</td>
<td>2.3</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>MST</td>
<td>17</td>
<td>0.632</td>
<td>-0.2</td>
<td>37</td>
<td>0.012*</td>
<td>1.4</td>
<td>15</td>
<td>0.943</td>
<td>-0.1</td>
</tr>
<tr>
<td>PSY</td>
<td>47</td>
<td>0.488</td>
<td>0.4</td>
<td>51</td>
<td>0.123</td>
<td>0.6</td>
<td>20</td>
<td>0.552</td>
<td>0.5</td>
</tr>
<tr>
<td>SPA</td>
<td>15</td>
<td>0.706</td>
<td>-0.3</td>
<td>13</td>
<td>0.262</td>
<td>1.5</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

### II. Majors Analyses (unpaired)

Unpaired comparisons allow larger population sizes and provide valid analyses between majors. [Every completed form represents a valid measure for that major, even though it can not be paired with another pre- or post-measurement.] In this section the same three attributes of R-MANX, SE and OE are analyzed.

A) Math Anxiety (R-MANX)

The population sizes for each of the four measurement points are shown in Table 4. Note that these populations are substantially larger than those observed for the paired comparisons in the previous section. [Not all students successfully complete a pre- and post-survey.]

### Table 4

Sizes for all major populations for R-MANX data for all for measurement points.

<table>
<thead>
<tr>
<th>RMANX, N</th>
<th>Pr105</th>
<th>Po105</th>
<th>Pr202</th>
<th>Po202</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR+MU</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>ENG</td>
<td>60</td>
<td>56</td>
<td>41</td>
<td>61</td>
</tr>
<tr>
<td>HIS</td>
<td>37</td>
<td>28</td>
<td>17</td>
<td>24</td>
</tr>
<tr>
<td>MAT</td>
<td>na</td>
<td>na</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>MST</td>
<td>24</td>
<td>22</td>
<td>51</td>
<td>56</td>
</tr>
<tr>
<td>PSY</td>
<td>57</td>
<td>59</td>
<td>62</td>
<td>69</td>
</tr>
<tr>
<td>SO+WG</td>
<td>31</td>
<td>42</td>
<td>36</td>
<td>37</td>
</tr>
<tr>
<td>SPA</td>
<td>20</td>
<td>18</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>non-STEM</td>
<td>210</td>
<td>208</td>
<td>179</td>
<td>217</td>
</tr>
<tr>
<td>STEM</td>
<td>24</td>
<td>22</td>
<td>66</td>
<td>81</td>
</tr>
</tbody>
</table>
Shown in Figure 1 are the average R-MANX scores for all populations of majors at all 4 measurement points. The R-MANX scores in Figure 1 are shown relative to the average of 64.01 observed for the K-5 Math major in course MTT202. For example, the SO/WG major exhibited an anxiety level that was 40% higher than the anxiety level of 64.01 in the pre105 measurement. (As might be expected, the K-5 Math major population exhibited the lowest anxiety levels of all of the K-5 major populations.) Hence, Figure 1 shows the anxiety levels relative to the “golden standard” of K-5 Math majors. The data in Figure 1 are consistent with the previous paired analyses. Decreases in anxiety are apparent for all majors except English. The majors of PSY, SO/WG and MST showed statistically significant decreases in anxiety between Pre105 and Post202 (p-values were less than 0.008). Before MAT105 the MST major had an anxiety level closest to that of the MAT major but was statistically distinct (p-value < 0.0002). After MTT202 the anxiety level of the MST major decreases to within 5% of that of the MAT major. A t-test between MAT and MST majors (pos202) gave a p-value of 0.195 (2-tail) indicating that there is not a statistically significant difference in anxiety between these two majors. Further, after MTT202 the majors of MAT and MST have anxiety levels that are statistically significantly lower than all other majors.

![Figure 1](image)

**Figure 1** R-MANX value for all majors, relative the average R-MANX score of the Math major population (64.01) observed in course MTT202.

These anxiety data allow an interesting question to be answered, “what fraction of each major population has high anxiety after the course MTT202?” Shown in Figure 2, is the fraction of MST majors and non-STEM majors (all non-STEM majors combined) that have an R-MANX score that is greater than 90, the anxiety level that delineates the top quartile. Hence, an R-MANX score of 90 represents a fairly high anxiety. Math majors are not included in Figure 2 since they produce zero members that meet the R-MANX>90 criteria. These data indicate that before MAT105 37.1% of all non-STEM majors have high anxiety, and this percentage decreases substantially to 24.8% after the course MTT202. By comparison, before MAT105 20.8% MST majors have high anxiety, and this percentage...
decreases to 7.1% after the course MTT202. The percentage of each major population having R-MANX>90 (Post202) are as follows: AR/MU=26.2%, ENG=32.8%, HIS=29.2%, PSY=18.8%, SO/WG=21.6%, SPA=20.0%.

Figure 2  Percentage of populations that have an R-MANX score greater than 90. Shown are two populations: (i) the STEM education major and (ii) all non-STEM majors combined.

B) Self-Efficacy (SE)
Shown in Figure 3 are average SE scores for all majors at all 4 measurement points. The population sizes for SE data are almost identical to those shown in Table 4 for R-MANX data. These SE scores are shown relative to the average of 54.0 observed for the K-5 Math major in course MTT202. As expected the Math major population did show the highest SE levels of all of the majors. Hence, Figure 3 shows the SE levels relative to the “golden standard” of Math majors. The data in Figure 3 are consistent with the previous paired analysis. Increases in SE are readily apparent for all majors, with Spanish being the exception.

The majors of ENG, PSY, SO/WG and MST showed statistically significant increases in SE between Pre105 and Post202 (p-values were less than 0.026). After MTT202 the SE level of the MST major increased to within 2% of that of the MAT major. A t-test between MAT and MST majors (pos202) gave a p-value of 0.095 (2-tail) indicating that there is not a statistically significant difference in SE (to the $\alpha=0.05$ level) between these two majors. Further, after MTT202 the majors of MAT, MST and AR/MU have SE levels that are statistically significantly higher than all other majors.
Previously published works have shown that math anxiety is well-correlated with math teaching self-efficacy. Figure 4 shows a plot of SE vs. R-MANX for all 10 individual major population averages for each of the 4 measurement points (pre- & post-105 and pre- & post-202). These data show a strong correlation (correlation coefficient = -0.87, slope $b_1 = -0.35$ and p-value less than 0.0001.)

C) Outcomes Expectancy (OE)
As was the case with the paired analyses, there were no statistically significant increases in OE for any majors. T-test analyses of all majors verified these results, yielding high p-values. Even though there were no significant differences, the Spanish major consistently had higher OE levels.
**Summary/Discussion:**

A summary of the measurements is given below for the three quantities measured: anxiety, self-efficacy (SE) and outcomes expectancy (OE).

(1) Math anxiety:

(a) The paired analyses showed that the two compulsory courses significantly decrease anxiety levels. All non-STEM majors showed significant decreases in anxiety in either MAT105 or MTT202. The largest decreases in anxiety occurred for the MST and Psychology majors. The MST and Psychology majors were also the only majors that exhibited “excess” decreases in anxiety when comparing the individual course decreases to the Pre105-Pos202 pairings, suggesting that there are other forces effecting anxiety. This “excess” anxiety decrease represents ~30% of the total decrease in anxiety.

(b) After MTT202 the Math and MST majors exhibited the lowest levels of anxiety, with these two populations exhibiting statistically lower anxiety levels compared to all other majors. The Math and MST majors exhibited math anxiety levels that were statistically equal \[ p(2\text{-tail}) = 0.195 \]. Our hypothesis that the MST major eventually achieved the same anxiety as the Math major was valid.

(c) The highest math anxiety levels were exhibited by the non-STEM majors of English (+30%), Sociology/Woman & Gender Studies (+25%) and History (+22%), where the number in parenthesis is the anxiety level relative to K-5 Math majors. Even though anxiety levels decrease substantially for the non-STEM majors, our data indicate that 1-in-4 non-STEM majors still have high math anxiety (R-MANX>90) after MTT202, potentially negatively impacting their STEM teaching capabilities. Moreover, since the size of these non-STEM majors is fairly large (~65% of the total) this implies that these majors produce a high absolute number of high anxiety students (after MTT202). This is compared to zero for the Math major and 1-in-14 for the MST majors. This ratio of 1-in-14 for high anxiety exhibited by the MST major is certainly not as preferable as the 0% for the Math major. However, it is important to note that the MST major is substantially larger, comprising ~27% of the total K-5 majors as compared to Math that comprises only ~5%.

(2) Math teaching self-efficacy (SE):

(a) The paired analyses showed that the two compulsory courses do significantly increase SE levels. All majors showed significant increases in SE levels. The largest increases in SE occurred for MST, Psychology and Art/Music. The MST major was the only major that exhibited an “excess” increase in SE when comparing the individual course increases to the Pre105-Pos202 pairing, suggesting that there are other forces effecting SE. This “excess” SE increase represented ~40% of the total increase in SE.

(b) The Math, MST and Art/Music majors exhibited the highest levels of SE, with these three populations exhibiting statistically significant higher SE levels compared to all other majors. A t-test between the Math and MST majors gave \[ p(2\text{-tail}) = 0.095, \]
indicating that there is no significant difference (to the $\alpha=0.05$ level). Our hypothesis that the MST major eventually achieved the same SE as the Math major was valid, although there is certainly less difference between the MST and Math majors in SE as compared to anxiety.

(c) The lowest SE levels were exhibited by the non-STEM majors of English, Spanish, History and Sociology/Woman & Gender Studies, with their SE levels 10-12% lower than Math majors.

(d) Using averages of the individual majors over the four measurement points, our data show that SE is highly correlated to math anxiety (corr. coefficient was -0.87).

(3) Math teaching outcomes expectancy (OE):

(a) The MST and History majors did show significant increases in OE for the course MTT202. However, taken as a whole, all populations had the same OE levels, indicating that the curriculum/experiences did not alter OE. Our hypothesis that the MST major achieved the same OE as the Math major was valid.

The data presented in this paper is, we believe, the only comprehensive study of math anxiety and math teaching beliefs by K-5 disciplinary major. The paired data analyses indicate that the two courses of MAT105 and MTT202 do substantially improve anxiety and SE levels. Unpaired analyses, with larger populations, produced similar results. The only major that exhibited anxiety and SE levels that were statistically equal the Math major after MTT202 was the MST major, and this was only after substantial improvements in anxiety and SE were achieved. By example, after course MTT202 1-in-4 non-STEM students still possess high math anxiety (R-MANX>90) compared to only 1-in-14 of the MST majors. The average math Scholastic Aptitude Test (SAT) score for our non-STEM K-5 major population is relatively high (~608) compared to the 2006/07 national average of ~480 for Education schools and is on par with the ~614 average for Engineering schools, so this 1-in-4 fraction for high anxiety is likely substantially larger nationally. Graduating a relatively large percentage of future teachers with high math anxiety only further perpetuates math (and STEM) anxiety since anxiety is passed on to the K-5(8) students, limiting the K-5(8) students affect and acumen in STEM content and activities.[4] We think the substantial improvements in anxiety and SE of the MST major is due to both their math and science curriculum (including MAT105 & MTT202) but especially their applied MST disciplinary curriculum. It is interesting to note that the Psychology major, which also has substantial context-driven mathematics content, showed the second largest improvements in anxiety and SE levels in the paired analyses (Tables 1 and 2). Further numerical evidence to the beneficial impact of additional context-driven math content is the observation that only the MST and Psychology majors exhibited substantially higher improvements in anxiety than would be predicted by the paired analysis of the individual MAT105 and MTT202 courses.
This study has not determined what aspects of the MST curriculum or experiences may have had the most beneficial impact on the anxiety and SE levels. However, some insight is gained by investigating anxiety levels for the MST specialization subpopulations. Since student names are collected as part of the original data set, a students’ specialization can be determined manually using either paper or electronic records. The MST major population is comprised of the following mixture of specializations: Technology & Engineering (~60%), Math (~25%) and Science (~15%). Therefore, the T&E specialization subpopulation, being over 2-fold larger than any other specialization, has a substantially larger impact on any quantity measured on the MST major population. Shown in Table 5 are R-MANX averages broken down by specialization of the STEM major. Table 5 shows population sizes (N), average R-MANX (Ave.) values and standard deviations (SD). Table 5(a) shows a comparison of R-MANX after the course MTT202 for all three specializations. The T&E specialization population attains a substantially lower anxiety and the smallest standard deviation. The mean R-MANX value after MTT202 for the T&E specialization subpopulation is 64.6, a level essentially identical to the value of 64 exhibited by the K-5 Math major. Table 5(b) shows the progression of the R-MANX value for the T&E specialization as this subpopulation progresses through the measurement points, demonstrating that the T&E specialization reduces anxiety level dramatically.

Table 5. R-MANX averages for specialization subpopulations of the MST major: (a) by specialization after MTT202 and for (b) T&E specialization for all 4 measurement points. [N is population size, Ave. is the R-MANX average and SD is the standard deviation.]

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The data in Table 5 indicate that the T&E specialization dominates the improvements in anxiety achieved by the MST major. This is interesting since this is the specialization that has the fewest requirements for classic math and science courses, and is the specialization that completes more T&E content. The T&E content has applied math content, motivated by realistic technology/engineering problems, spread throughout the curriculum. This applied content, and context, is consistent with previous papers on math anxiety remediation.[4,23] The MST curriculum produces a large number of future teachers that have low math anxiety and high math teaching self-efficacy, and are highly likely to have low anxiety and high self-efficacy in all STEM subjects. [Previous studies have correlated math anxiety with science anxiety [6], and the MST curriculum is very rich in T&E content and activities.] These attributes of “integrated-STEM literacy” enable the MST major graduates to truly be
integrated-STEM teachers, integrating STEM as well as non-STEM content, resulting in a variety of benefits to K-12 students.

In summary, we postulate that the applied and hands-on nature of the K-5 MST major assists students in improving their levels of math anxiety and math teaching SE to the level of K-5 math majors. We are therefore in agreement with Gresham [23] that math anxiety can be reduced through math training and education and with Beilock et al. [4] that more care be taken to develop strong math skills and positive attitudes in prospective teachers. Additionally, producing prospective teachers with high levels of SE will lead to elementary school classrooms that have higher student academic achievement.[21] We are encouraged by the findings of Philippou and Christou [24] that showed that even when pre-service teachers bring negative feelings and misconceptions about math into their initial training, teacher training can positively influence their attitude toward math. Hence it would seem advisable that, as teacher educators, we address the content knowledge, methodology and activities needed for teachers to be successful, including reductions in math anxiety and increases in self-efficacy.

Future work / questions:
This work directly raises the question of whether or not additional applied math (or integrated-STEM) content be added to non-STEM curricula, thus reducing the number of graduates with high math anxiety and low SE. [Or for States that do not require disciplinary majors for K-5 teacher candidates, if enough applied math (or integrated-STEM) content is being required.] This work strongly suggests that the applied, contextual-driven math content is effective in reducing anxiety and increasing SE. Therefore, simply “any additional math course” may likely not be a solution to lowering anxiety (and increasing SE) since a math anxious student is likely to view yet another “math” course with trepidation. In contrast, a course driven by context (“applied”) is likely to be perceived as less intimidating. The authors have searched literature for a measure of math anxiety (pre-service) for a wide variety of teacher preparation institutions across the nation (using the same instrument) but have not found one. Such an exercise would seem useful simply to assess the depth of such a potential problem. For example, as a nation, are we producing large numbers of highly math anxious K-5(8) teachers that then pass this trait onto their K-5(8) students? If this is true, then a large step towards “STEM remediation in K-12” would be to ensure graduation rates of K-5(8) teachers with low anxiety, perhaps achieved through more applied, context-driven math content. Another interesting area of future research would be to assess the persistence of math anxiety after graduation and into the beginning teaching years. It might be expected that anxiety levels would diminish due to the teacher gaining real-world experience. On the other hand, some teachers’ real-world experiences may degrade anxiety levels.

This work has not shown “directly” that integrated-STEM content reduces anxiety more so than traditional math content experiences. Therefore, it may be possible to compare anxiety
levels of a particular math-oriented pre-service course where certain sections are taught with substantially more applied and hands-on activities while other sections are not. However, this does pose an ethical issue.

The existing data set might also provide additional insights. For example, does a context-driven, applied STEM content course taken at the same time as MAT105 or MTT202 result in preferential improvements in anxiety and/or SE? Or does a context-driven, applied STEM content course that is completed between MAT105 and MTT202 preferentially benefit anxiety or SE levels? Measurements of math anxiety and SE in a pre-post format for individual math-oriented integrated-STEM courses may also prove useful. Additionally, collecting additional data for the current research format would provide larger populations, aiding the statistical strength, and allow for conclusions for additional majors. Finally, if it can be determined that certain features/components of applied curriculum are more effective in remediating anxiety then these features could be more effectively integrated into “non-STEM” teacher preparation programs.

References


