On the Importance and Measurement of Pre-Service Teachers' Efficacy to Teach Statistics: Results and Lessons Learned from the Development and Testing of a GAISE-Based Instrument

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Abstract
Pre-service teachers have been the focus of much research, including studies that concentrate on teacher preparation and/or teacher beliefs and attitudes. An idea central to teacher beliefs and attitudes is teacher self-efficacy. Research about teacher self-efficacy in science and mathematics education has shown that levels of self-efficacy are related to content knowledge, pedagogical content knowledge, and beliefs and attitudes regarding the content. Self-efficacy to teach statistics is potentially a more complex concept; programs to prepare teachers tend to have methods courses that focus on teaching mathematics, but rarely any that focus exclusively on teaching statistics. Our CAUSE-supported research team developed a new instrument designed to measure levels of this construct based on the GAISE guidelines for Pre-K-12 curriculum and those state standards for teacher knowledge and student learning outcomes that have specific statistics requirements.

Key Words: Teacher efficacy, self-efficacy, GAISE, teaching statistics

1. Literature Review

Pre-service teachers have been the focus of much research, including studies that focus on teacher preparation and/or teacher beliefs and attitudes. An idea central to teacher beliefs and attitudes is teacher efficacy. Teacher efficacy has been defined as a teacher's "belief that they have the skills to bring about student learning" (Ashton, 1985, p. 142); Smith, 1996; Gresham, 2008). Teacher efficacy is important as it affects teacher motivation, willingness to use more innovative techniques, student achievement, and time spent teaching certain concepts (Czerniak, 1990; Riggs & Enochs, 1990; Wenta, 2000).

1.1 Research in Mathematics and Science Education
Research about teacher efficacy in mathematics and science education has shown that levels of teacher efficacy are related to teacher content knowledge, teacher pedagogical content knowledge, and teacher beliefs and attitudes regarding the content (Cakiroglu,

2000; Gresham, 2008; Huinker & Madison, 1997; Swars, 2005; Wenta, 2000). A mixed methods study with a pre-test post-test design using both the Science Teaching Efficacy Beliefs Instrument (STEBI-B) and the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) and semi-structured interviews with pre-service elementary school teachers (Huinker & Madison, 1997) showed that content methods courses improved the pre-service teachers efficacy about teaching mathematics and science. Another mixed methods study by Swars (2005) used the MTEBI to identify pre-service teachers with high and low mathematics teaching efficacy. Her interviews with the selected pre-service teachers led to the discovery that both students with high and low levels of efficacy have had negative experiences with math and that previous math experience influenced what teaching strategies they would be comfortable. Based on results of the MTEBI and the Mathematics Anxiety Rating Scale (MARS) from 156 pre-service teachers and semi-structured interviews completed with 20 of the initial respondents, Gresham (2008) found that "pre-service teachers' attitudes toward mathematics play a crucial role in their beliefs to teach mathematics effectively" (p. 182).

A study of pre-service elementary school teachers in Turkey (Isiksal & Cakiroglu, 2006) investigated the relationship between mathematics teaching self-efficacy and mathematics self-efficacy as well as the university attended and the grade level of the pre-service teacher. The results revealed that pre-service teachers' levels of mathematics self-efficacy, as measured by the Mathematics Self-Efficacy Scale (MSES), were significantly positively correlated with levels of efficacy to teach statistics, as measured on the MTEBI. In addition, the university the pre-service teacher attended was not significant but it should be noted that only two universities in Turkey were used for the study. In fact, the authors stated that "both of the universities have similarities in terms of their educational policies, and this could be one of the reasons that there was no significant difference between pre-service teachers' efficacy beliefs toward teaching mathematics" (p. 83). There was no significant difference for grade level within the universities in terms of teacher efficacy.

In a summary of previous research, Smith (1996) stated that teacher efficacy is developed before the teacher enters the classroom. The development occurs during teacher preparation activities such as content and pedagogy courses, student teaching, classroom observations. Through interviews with teachers, Hoy (2000) found that teacher efficacy is hard to change once it has developed. This research shows the importance of the introduction of experiences in the pre-service mathematics that lead to efficacy development.

1.2 Research in Statistics Education

Initially, much of the research in the statistics education community has addressed student misconceptions and understanding regarding specific statistical concepts. As a result of the development of the Guidelines for Assessment and Instruction in Statistics Education (GAISE) (Franklin et al., 2007) as well as recommendations from the NCTM, (2000), research has started to focus on teacher preparation to teach as well as attitudes towards the concepts presented in GAISE and the revised Pre-K-12 mathematics curriculum.

Teacher efficacy to teach statistics is a potentially more complex concept than in mathematics or science education as teachers of mathematics and statistics in grades K-8 tend to be graduates of mathematics education programs rather than statistics undergraduate majors or graduate students. However, as state-mandated standards

incorporate statistics and probability into K-8 mathematics curricula, exploring teacher efficacy to teach statistics increases in importance.

Following a change in the mathematics curriculum in Australia, a study of in-service teachers was conducted using a questionnaire and semi-structured interviews to look at their confidence to teach concepts of chance as a function of their background (Watson, 2000). Although most of the teachers had some exposure to statistical concepts, there were topics with which the teachers struggled with in terms of constructing lesson plans. Their teacher efficacy levels were lower for more complex concepts that may not have been part of their preparation background.

In Estrada and Batanero (2008), three studies conducted in Spain about teacher attitudes towards statistics are described. In the first study, both pre-service and in-service teachers were given an instrument with items to measure their attitudes towards statistics as well as measure the number of mathematics courses with statistical content. The statistical analysis showed that as the number of courses with statistics exposure increased, the attitudes of the teachers toward statistics improved. While the second study contained only pre-service teachers, the findings were the same. The third study was qualitative in nature. The pre-service teachers were given a questionnaire regarding attitudes toward statistics and were instructed to explain their response to each item. The responses were coded and turned into themes. The results showed that lack of knowledge or training as well as overly formal training led to negative attitudes, while perceptions regarding the easiness of the topic, prior good learning experiences, and perceived value for their work or the students' education led to positive attitudes.

Lancaster (2008) conducted a study which administered five questionnaires to pre-service teachers in a mathematics content course and the pre-requisite mathematics course that was the pre-requisite for the content course. The questionnaires measured general attitudes towards statistics, self-efficacy toward current ability to perform statistics, current self-efficacy to learn statistics, statistical reasoning, and attitudes toward the pursuit of continuing professional development in statistics. One of the quantitative analyses showed that the pre-service teachers' attitude towards statistics influenced their self-efficacy to learn statistics.

Having positive experiences with learning and teaching statistical concepts in the mathematics educator preparation curriculum should improve pre-service mathematics teachers' efficacy to teach statistics as well as positively impact their attitudes toward statistics. However, a gap in the research exists in determining which type of experiences with statistics lead to higher teacher efficacy as well as identifying what other factors influence the development of statistics teaching efficacy as well as teacher attitudes towards statistics in pre-service teachers. Hence, this study looks at these issues with the aim of influencing pre-service mathematics teacher preparation in statistics.

2. Methods

The instrument development process was comprised of three steps. The first step entailed studying the GAISE guidelines and using them as the representative behaviours we were interested in investigating. Step two was to match these expectations to the state standards by comparing the behaviours to both student and teacher state standards and determining how they aligned. The final step was to construct the self-efficacy items using language that blended the state standards and the GAISE guidelines.

To determine the appropriateness and teacher understanding of the wording of the instrument items, 12 in-service middle and elementary school teachers attending a course to become Mathematics Specialists in a mid-Atlantic state were asked to verify and comment on the language. Revisions to the item wording were completed based on the authors' input as well as the remarks from these teachers. The final instrument consisted of 12 items corresponding to Level A (expectation for primary grades) and 15 items corresponding to Level B (expectations for middle grades) of the GAISE guidelines. Respondents were asked to rate their confidence in *teaching middle school students* using a scale of 1 – 6 where 1 = not at all confident, 2 = only a little confident, 3 = somewhat confident, 4 = confident, 5 = very confident, 6 = completely confident.

2.1 Sample

The revised instrument was given to 23 pre-service middle school teachers and 21 non-education majors at a Doctorate-granting public university in the south-central United States. The middle school pre-service teachers constitute almost the entire cohort of students seeking middle school certification in a given year. Table 1 summarizes the demographic characteristics of the participants. Students were surveyed during either an introductory statistics class or a mathematics education class for future middle school teachers.

Table 1: Demographics of Participants

Characteristic		*Distribution*	
Major	4- 8 grade teacher (23)	Non-education (21)	
Gender	Female (33)	Male (11)	
Instructional area for pre-service teachers	All areas (5)	Mathematics (16)	Science (3)
Had college-level statistics	0 courses (1)	1 course (42)	2 or more courses (1)
Had statistics pedagogy	0 courses (37)	1 course (6)	2 or more courses (1)

3. Results

Percentages of non-education and pre-service middle school teachers by level of confidence for each self-efficacy item are shown in Figures 1 and 2. One result that stands out is that at least 50% of the participants in both groups feel confident or better about teaching statistics for middle school students. Another result that stands out is that we observe three items for which none of the pre-service middle school teachers were "completely confident." These correspond to teaching students about 1) the difference between a question based on data that vary and a question based on a deterministic model, 2) describing numerically the strength of association between two variables using linear models, and 3) interpreting measures of association.

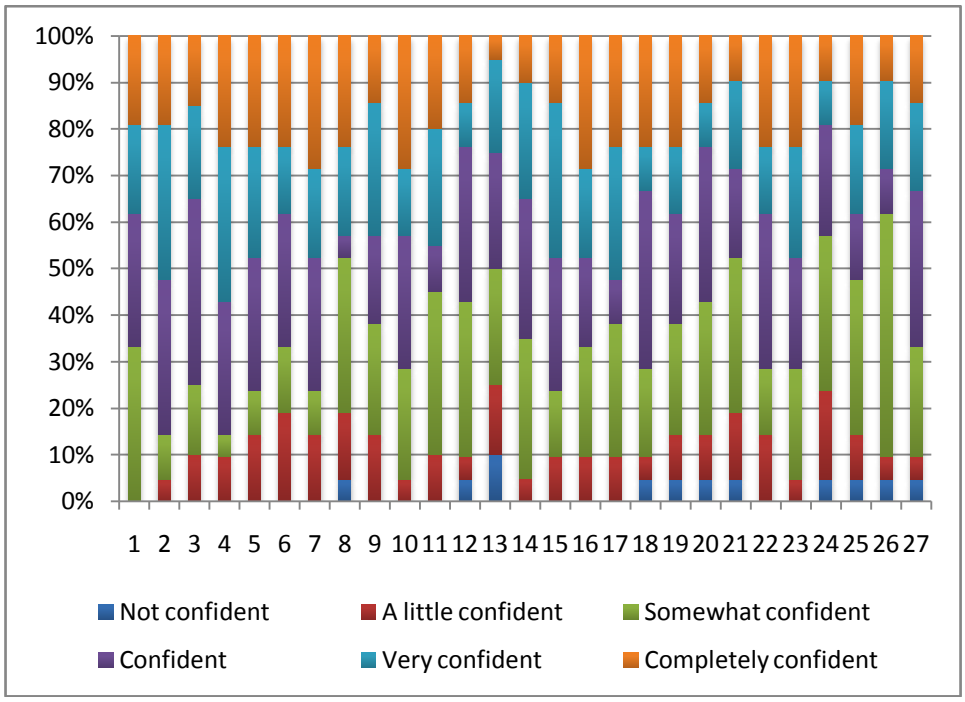

Figure 1: Percent of non-education majors by level of confidence for each self-confidence item

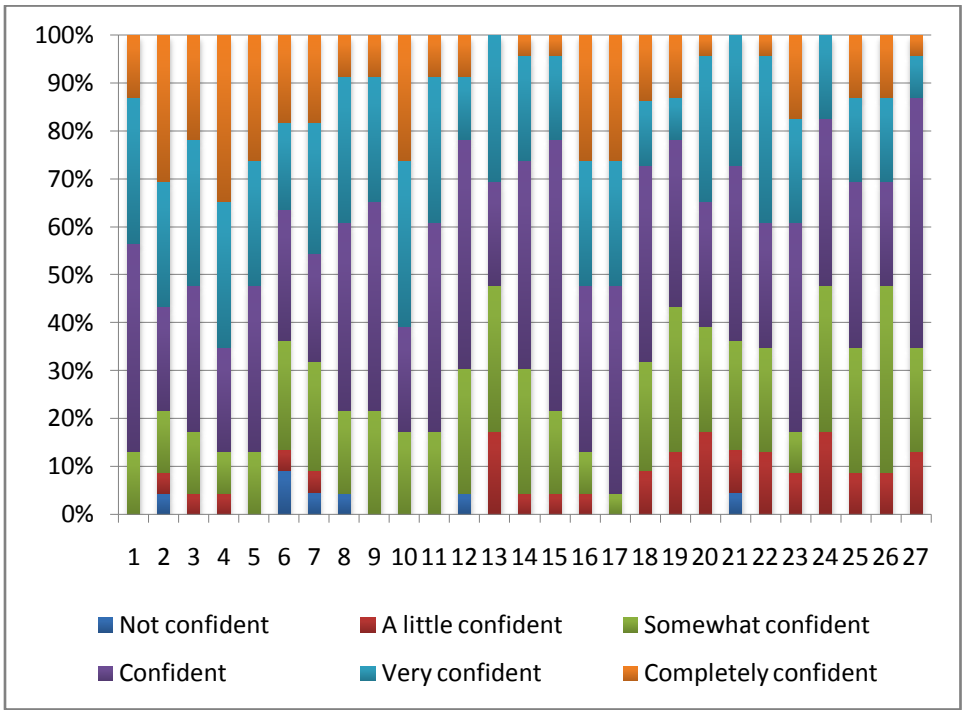

Figure 2: Percent of pre-service middle school teachers by level of confidence for each self-confidence item

Further, we compared the results for differences among the two groups of participants with regard their overall level of confidence and we found that non-education majors are more confidence but the difference is not significant. We also observed larger variation among non-education majors. When comparing differences between those items measuring self-efficacy at the primary level (Level A) and at the middle grades level (Level B), we found that participants feel more confident teaching at the primary level ($p < 0.12$). The comparison was possible by creating a standardized confidence level scale for each participant by computing the sum of the corresponding level of confidence numerals of each item and scaling it to 100 points (see Figure 3). These results should be taken with caution since we have relatively small sample sizes.

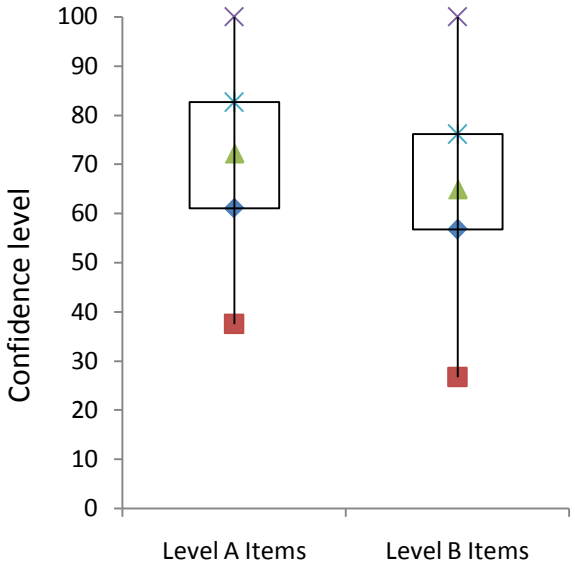

Figure 3: Distribution of the confidence level of all participants by Level A and Level B items

4. Future Plans

During the 2009-2010 academic year, we will be conducting a large scale validation with 200 or more participants from institutions around the country. We are also developing a content validity instrument to measure the degree of association between the self-efficacy construct and the statistical knowledge of the pre-service teacher.

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