Establishing Factorial Validity of the Mathematics Teaching Efficacy Beliefs Instrument

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The Mathematics Teaching Efficacy Belief Instrument (MTEBI) for preservice teachers resulted from the modification of the Science Teaching Efficacy Belief Instrument STEBI-B. The MTEBI consists of 21 items, 13 items on the Personal Mathematics Teaching Efficacy (PMTE) subscale and eight items on the Mathematics Teaching Outcome Expectancy (MTOE) subscale. Possible scores on the PMTE scale range from 13 to 65; MTOE scores may range from 8 to 40. The first version of the MTEBI had 23 items like the STEBI-B; however, subsequent analysis in this validation required two items be dropped. Reliability analysis produced an alpha coefficient of 0.88 for the PMTE scale and an alpha coefficient of 0.75 for the MTOE scale ($n = 324$). *Confirmatory factor analysis indicates that the two scales (PMTE and MTOE) are independent, adding to the construct validity of the MTEBI.*

The purpose of this study was to establish factorial validity of the newly developed Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) for preservice elementary teachers. Several efficacy beliefs instruments have been developed by modifying the original Science Teaching Efficacy Beliefs Instrument (STEBI-A). Each of these instruments were subject specific and had factorial validity established by way of traditional factor analysis. The MTEBI discussed here, however, was subjected to a more rigorous confirmatory factor analysis, utilizing a structural modeling program called EQS.

Over the past 10 years, several adaptations of the original Science Teaching Efficacy Beliefs Instrument (Riggs & Enochs, 1990) have been modified to address subject-specific teaching. Several of these adaptations relied on already established validity. Because validity assessments are ongoing and never ending, the authors formally assessed the Mathematics Teaching Efficacy Beliefs Inventory used in the Huinker and Madison (1997) study to provide a formal check of validity for this instrument.

Background

"All our efforts to make the mathematics curriculum consistent with the National Council of Teachers of Mathematics (NCTM) standards will fail if teachers beliefs about mathematics do not become aligned with those of the reform movement" (Battista, 1994, p. 470). Haney and Lumpe (1995), Borko and Putnam (1995), and Haney, Czerniak, and Lumpe (1996), indicated that the use of effective and innovative science (mathematics) instruction, promoted by recent national reform efforts, hinges on the teachers' self-efficacy beliefs about science (mathematics) teaching and knowledge about the reform effort itself. De Mesquita and Drake (1994) demonstrated a direct relationship between the perceived levels of teacher efficacy and attitudes toward innovative reform practices. It is not sufficient to prepare teachers of mathematics in areas of content and pedagogy. Borko and Putnam further stated that "... they must acquire richer knowledge of subject matter, pedagogy, and subject-specific pedagogy; and they must come to hold new beliefs in these domains" (1995, p. 60).

Theoretical Framework

Beliefs are part of the foundation upon which behaviors are based. Several studies investigating teacher efficacy beliefs indicate that these beliefs may account for individual differences in teacher effectiveness (Armor et al., 1976; Berman & McLaughlin 1977; Brookover et al., 1978). Beliefs have been closely associated with behavior in Bandura's (1981) theory of social learning. Bandura suggested that people develop a generalized expectancy concerning action-outcome contingencies based upon life experiences. In addition, they develop specific beliefs concerning their abilities to cope with change. Bandura (1986) called this self-efficacy (1986). Behavior is enacted when people not only expect specific behavior to result in desirable outcomes (outcome expectancy), but they also believe in their own ability to perform the behaviors (self- efficacy). Bandura (1997) indicated that efficacy beliefs depend upon situational specificity; that is, efficacy beliefs depend on the situation or context relative to the action or task to be performed. In discussing situational specificity, Pintrich and Schunk (1996) posited, "Related to this situational specificity, self-efficacy beliefs are assumed to be much more dynamic, fluctuating, and changeable beliefs than the somewhat more static and stable self-concept and self-competence beliefs" (1996, p. 93).

If Bandura's theory of self-efficacy is applied to the study of teachers, one might predict that

> . . . teachers who believe student learning can be influenced by effective teaching (outcomes 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 (Gibson & Dembo, 1984, p. 570).

Related Research

The examination of self-efficacy and outcome expectancy in relation to teaching has been the focus of study by several researchers (e.g. Ashton & Webb, 1986; Enochs & Riggs, 1990; Gibson & Dembo, 1984; Guskey, 1988; Woolfolk & Hoy, 1990). Personal teaching efficacy has been defined as a belief in one's ability to teach effectively and teaching outcome expectancy as the belief that effective teaching will have a positive effect on student learning. Research on efficacy of teachers suggests that behaviors such as persistence on a task, risk taking, and use of innovations are related to degrees of efficacy (Ashton, 1985; Ashton & Webb, 1986). For example, highly efficacious teachers have been found to be more likely to use inquiry and student-centered teaching strategies, while teachers with a low sense of efficacy are more likely to use teacher-directed strategies, such as lecture and reading from the text (Czerniak, 1990).

Methodology

Subjects

Since this study was designed to test the validity of the MTEBI instrument, a sample of elementary preservice mathematics teachers in training were deemed the appropriate population for the study. Students in methods courses were utilized, since this course provided a common point in students' preservice education and is generally taught late in their training. Subjects were recruited from elementary methods classes in session from college and university settings in Wisconsin (three sites), California, South Carolina, and Michigan. The sites were chosen because of already existing collaboration with the methods instructors at each of these institutions. At each site, students in elementary mathematics methods classes were asked to fill out the instrument. The MTEBI for preservice teachers was administered at the end of each course. The total sample for this study consisted of 324 preservice teachers (58 male and 266 female).

Instrument Modification

Several efficacy beliefs instruments have been developed by modifying the original STEBI-A (Appendix A). Each of these instruments were subject specific and had factorial validity established by way of traditional factor analysis. The MTEBI discussed here, however, was subjected to a more rigorous confirmatory factor analysis utilizing a structural modeling program called EQS.

The MTEBI for preservice teachers resulted from the modification of the preservice STEBI-B (Enochs & Riggs, 1990). Items were changed to reflect future mathematics teaching beliefs. The following sample items are:

> Self-efficacy: Even if I try very hard, I will not teach mathematics as well as I will most subjects;
> Outcome Expectancy: The mathematics achievement of some students cannot generally be blamed on their teachers.

Each item has five response categories: *strongly agree, agree, uncertain, disagree,* and *strongly disagree.* The MTEBI is comprised of two subscales, personal mathematics teaching efficacy (PMTE) and mathematics teaching outcome expectancy (MTOE). Possible scores on the PMTE scale range from 13 to 65; MTOE scores may range from 10 to 50.

Analysis

Item Analysis

Item analysis was conducted for both scales of the 23-item MTEBI. Of the 23 items, two had item-total item correlations less than 0.30. This low correlation was considered less than exemplary by Robinson, Shaver, and Wrightsman (1991) and were dropped from further analysis.

Results of the item analysis appear in Table 1. The final MTEBI consists of 21 items, 13 items on the PMTE subscale and eight items on the MTOE subscale. Possible scores on the PMTE scale range from 13 to 65; MTOE scores may range from 8 to 40. For the final PMTE, five items were written in a positive orientation and eight were written negatively. The final MTOE included all eight positively worded items. Negatively worded items were recoded for the analysis. Reliability analysis produced an alpha coefficient of internal consistency (Cronbach alpha) of 0.88 for the PMTE scale and an alpha coefficient of 0.77 for the MTOE scale.

Construct Validity: Confirmatory Factor Analysis

In the process of construct validation, the distinction needs to be made between exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). In general EFA is concerned with the determination of how many factors are necessary to explain the relationships between a set of items and to estimate these relationships in terms of factor loadings. This is done without an explicit model or hypothesis regarding the structure. CFA, on the other hand, relies on a specific hypothetical or expected factor structure and serves to confirm its presence (or lack thereof) in the data set at hand. In general, when theoretical relationships or a factor structure is specified a priori, CFA is the preferred approach. In addition, EFA places greater restrictions on the validation effort as compared to CFA. For example, in EFA a factor loading for each item on each factor will be estimated, whereas in CFA items can be constrained not to load on certain factors if the validation theory so instructs. In addition, CFA allows certain factors to correlate, whereas in EFA one must specify uncorrelated factors or correlated factors where all factors correlate with one another. Further, EFA assumes that item errors (variance in items not related to the factors) are uncorrelated, whereas in CFA selected correlated errors may be specified as part of the model being investigated. In summary, CFA provides a more flexible, theoretically guided technique to assist in the validation of measurement instruments than does EFA. (See Pedhazur and Schmelkin, 1991, for further details on the distinctions between EFA and CFA.)

Table 1
Final Corrected Item-Total Scale Correlations and Factor Loadings

Measure	Item	Positive-Negative Wording	Item-Total Correlations
PMTE (SE)	I 2	P	0.36
	I 3	N	0.62
	I 5	P	0.54
	I 6	N	0.56
	I 8	N	0.55
	I 11	P	0.59
	I 15	N	0.50
	I 16	P	0.62
	I 17	N	0.62
	I 18	N	0.58
	I 19	N	0.65
	I 20	P	0.47
	I 21	N	0.61
Total SE Scale Alpha = 0.88			
MTOE (OE)	I 1	P	0.49
	I 4	P	0.49
	I 7	P	0.42
	I 9	P	0.42
	I 10	P	0.48
	I 12	P	0.45
	I 13	P	0.53
	I 14	P	0.49
Total OE Scale Alpha = 0.77			

The factor structure of the MTEBI was examined through CFA using the EQS program (Bentler, 1993). CFA compares the empirical data with a hypothesized model to determine if the data may have reasonably resulted from the hypothesized model. How well the data fit the specified model in CFA using the EQS program depends in the simultaneous consideration of several criteria. In evaluating model fit, it is important to examine the model chi-square statistics; the smaller this chi-square statistic, the better the model fit. Because the chi-square statistic is sensitive to sample size (larger samples result in larger chi-square statistics for comparable levels of model fit), alternative measures of model fit should be considered as well.

Two such measures used in this study were Akaike's (1987) Information Criteria (AIC) and the Comparative Fit Index (CFI, Bentler, 1990). It has also been suggested that the chi-square to degree-of-freedom ratio can be used as a rough indication of model fit, with values below 2.00 indicating a reasonable fit (Byrne, 1989). In addition, the standardized residuals of the sample covariance matrix and the hypothesized covariance matrix should be small and evenly distributed. Finally, EQS uses the Lagrange Multiplier (LM, Bentler, 1993) test to determine which, if any, parameters in the model could be modified to improve the fit between the model and the data. It was important that such post hoc model modifications be theoretically justified, however. Details associated with CFA, the EQS program, and considerations regarding model fit and modification may be found in Bentler (1993).

The initial model tested in this study hypothesized a simple two factor model with the identified self-efficacy items and outcome expectancy items loading on two independent factors which were set free to covary. Model fit statistics associated with this initial model are shown in the first row of Table 2.

The standardized residuals for this model were reasonable small and evenly distributed, and the AIC was well below the model's chi-square, indicating reasonable model fit. However, the chi-square/*df* ratio was somewhat high, and the CFI was lower than the .90 value generally considered an indication of good model fit. Because of this, it was determined that an improved model fit be sought. The results of the LM tests revealed a highly significant model misfit associated with the error components of Items 12 and 5 and modest misfit associated with the three error covariances associated with Items 3, 6, and 8. Since all of these items were on the self-efficacy scale, and correlated errors among items on the same scale was not an uncommon occurrence, the model was modified by setting these four parameters free to vary from their previously fixed values of zero.

The fit statistics associated with the modified model are show in the second row of Table 2. These statistics show a reasonably good model fit with respect to all of the criteria discussed earlier. In addition, the modified model represents a significant ($p < .01$) improvement over the model specified initially. LM tests, which followed this analysis, suggested no more parameter adjustments that could be theoretically justified. The factor structure associated with the final model appears in Figure 1. This confirmatory factor analysis indicated that the two scales (PMTE and MTOE) are independent, adding to the construct validity of the MTEBI.

Conclusions

Consistent with prior research utilizing the STEBI instruments, the MTEBI appears to be a valid and reliable assessment of mathematics teaching self-efficacy and outcome expectancy. As mentioned earlier, the validation of instruments continues to be an ongoing process. The use of the MTEBI will require continued vigilance in terms of study-specific assessment of reliability and cross-validation. Additional validity assessment is needed in the form of predictive validity. As more research studies are conducted, specific attention should be made to the capabilities of this instrument to predict teacher effectiveness and the propensity of mathematics teachers to become reformers.

Further Research

Research on preservice teacher preparation has not consistently dealt with beliefs. Content knowledge and teacher beliefs are both important in teacher preparation and should be addressed. Central to further research is a need to determine how efficacy beliefs influence teaching practice and subsequent student achievement. Possible research topics for future study include

- Mathematics teaching efficacy beliefs and their impact on the quality of the student teaching experience.
- Longitudinal studies of the mathematics teaching efficacy beliefs as preservice teachers move from novice to experienced teachers.
- Methods of enhancing preservice mathematics teaching efficacy beliefs.
- Mathematics teaching efficacy as a predictor of student achievement.
- Exploration of how mathematics teaching efficacy is developed including those factors contributing to high teacher efficacy.

Table 2
Model Fit Statistics for Initial and Modified Model

Model	Chi Square	DF	AIC	CFI	Average Standard Residuals
Initial	439.80	188	63.80	.869	.484
Modified	346.70	184	2.23	.919	.445

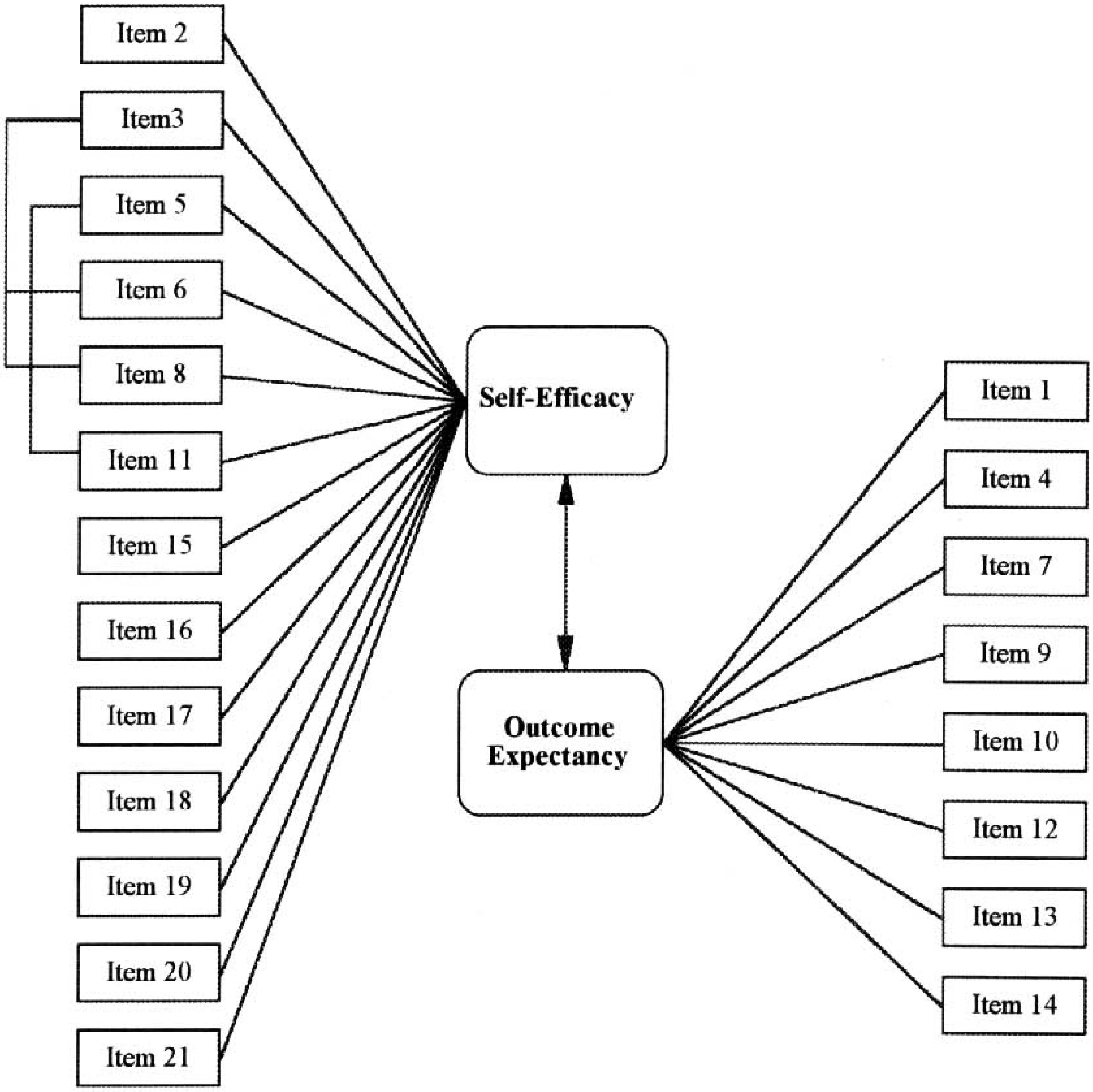

Figure 1. *Factor Structure of MTEBI Scale Items*

- The development of efficacy beliefs as a focus of teacher education programs.

For further discussion of teaching self-efficacy beliefs the authors suggest, Bandura (1997), Tschannen-Moran, Hoy, and Hoy (1998), and Ross (1994). A copy of the MTEBI final instrument is found in Appendix B. In order to facilitate the use of the MTEBI, coding and scoring instructions are found in Appendix C.

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Appendix A

Items and Reliability Coefficients from Instruments Developed and Modified from the STEBI-A

Source	Instrument	Sample Items (Alpha)	Reliability
Science Teaching Efficacy Beliefs: Elementary Inservice (Riggs & Enochs, 1990)	STEBI-A	SE: Even when I try very hard, I do not teach science as well as I do most subjects. OE: The low science achievement of some students cannot generally be blamed on their teachers.	SE 0.92 OE 0.77
Science Teaching Efficacy Beliefs: Elementary Preservice (Enochs & Riggs, 1990)	STEBI-B	SE: Even if I try very hard, I will not teach science as well as I will most subjects. OE: The low science achievement of some students cannot generally be blamed on their teachers.	SE 0.90 OE 0.76
Chemistry Teaching Self-Efficacy Beliefs: Middle School Inservice (Rubeck & Enochs, 1991)	STEBI-CHEM	SE: Even when I try very hard, I do not teach chemistry as well as I do most subjects. OE: The low science achievement of some students in the chemistry section of science cannot generally be blamed on their teachers.	SE 0.88 OE 0.80

Appendix B

MTEBI (Mathematics Preservice)

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA	A	UN	D	SD
Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree

1.	When a student does better than usual in mathematics, it is often because the teacher exerted a little extra effort.	SA	A	UN	D	SD
2.	I will continually find better ways to teach mathematics.	SA	A	UN	D	SD
3.	Even if I try very hard, I will not teach mathematics as well as I will most subjects.	SA	A	UN	D	SD
4.	When the mathematics grades of students improve, it is often due to their teacher having found a more effective teaching approach.	SA	A	UN	D	SD
5.	I know how to teach mathematics concepts effectively.	SA	A	UN	D	SD
6.	I will not be very effective in monitoring mathematics activities.	SA	A	UN	D	SD
7.	If students are underachieving in mathematics, it is most likely due to ineffective mathematics teaching.	SA	A	UN	D	SD

8.	I will generally teach mathematics ineffectively.	SA	A	UN	D	SD
9.	The inadequacy of a student's mathematics background can be overcome by good teaching.	SA	A	UN	D	SD
10.	When a low-achieving child progresses in mathematics, it is usually due to extra attention given by the teacher.	SA	A	UN	D	SD
11.	I understand mathematics concepts well enough to be effective in teaching elementary mathematics.	SA	A	UN	D	SD
12.	The teacher is generally responsible for the achievement of students in mathematics.	SA	A	UN	D	SD
13.	Students' achievement in mathematics is directly related to their teacher's effectiveness in mathematics teaching.	SA	A	UN	D	SD
14.	If parents comment that their child is showing more interest in mathematics at school, it is probably due to the performance of the child's teacher.	SA	A	UN	D	SD
15.	I will find it difficult to use manipulatives to explain to students why mathematics works.	SA	A	UN	D	SD
16.	I will typically be able to answer students' questions.	SA	A	UN	D	SD
17.	I wonder if I will have the necessary skills to teach mathematics.	SA	A	UN	D	SD
18.	Given a choice, I will not invite the principal to evaluate my mathematics teaching.	SA	A	UN	D	SD
19.	When a student has difficulty understanding a mathematics concept, I will usually be at a loss as to how to help the student understand it better.	SA	A	UN	D	SD
20.	When teaching mathematics, I will usually welcome student questions.	SA	A	UN	D	SD
21.	I do not know what to do to turn students on to mathematics.	SA	A	UN	D	SD

Appendix C

Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) Scoring Instructions

Step 1. Item Scoring: Items must be scored as follows: Strongly Agree = 5; Agree = 4; Uncertain = 3; Disagree = 2; and Strongly Disagree = 1.

Step 2. The following items must be reversed scored in order to produce consistent values between positively and negatively worded items. Reversing these items will produce high scores for those high and low scores for those low in efficacy and outcome expectancy beliefs.

Item 3	Item 17
Item 6	Item 18
Item 8	Item 19
Item 15	Item 21

In SPSSx, this reverse scoring can be accomplished by using the recode command. For example, recode ITEM3 with the following command:

```
RECODE  ITEM3  (5=1)  (4=2)  (2=4)  (1=5)
```

Step 3. Items for the two scales are scattered randomly throughout the MTEBI. The items designed to measure Personal Mathematics Teaching Efficacy Belief (SE) are as follows:

Item 2	Item 11	Item 18
Item 3	Item 15	Item 19
Item 5	Item 16	Item 20
Item 6	Item 17	Item 21
	Item 8	

Items designed to measure Outcome Expectancy (OE) are as follows:

Item 1	Item 9	Item 13
Item 4	Item 10	Item 14
Item 7	Item 12	

Note: In the computer program, DO NOT sum scale scores before the RECODE procedures have been completed. In SPSSx, this summation may be accomplished by the following COMPUTE command:

COMPUTE SESCALE = ITEM2 + ITEM3 + ITEM5 + ITEM6 + ITEM8 + ITEM11 + ITEM15 + ITEM16 + ITEM17 + ITEM18 + ITEM19 + ITEM20 + ITEM21

COMPUTE OESCALE = ITEM1 + ITEM4 + ITEM7 + ITEM9 + ITEM10 + ITEM12 + ITEM13 + ITEM14