Development and Validation of the Engineering Teaching Efficacy Belief Instrument

The Subject/Problem

Although previous science standards recommended the integration of engineering in K-12 education to enhance science learning (e.g., *Benchmarks for Science Literacy,* 1993), the Next Generation Science Standards [NGSS] (2013) placed a special emphasis on engineering and made engineering as an integral part of science education. The NGSS recommended the integration of engineering both as an important concept and as a pedagogical teaching approach to teach science. This means that the NGSS calls for teachers to update their curricula not only to engage their students in engineering practices but also to introduce it as a disciplinary core idea. Although elementary teachers are expected to introduce engineering starting at lower elementary grades, they do not have enough background in engineering. Only 1% of elementary teachers take engineering courses during their undergraduate program (Banilower et al., 2013). It is, therefore, necessary to determine the status of teachers' engineering teaching practices to identify the areas that need to be addressed and improved. As an important construct for identifying and predicting teachers' instructional practices, the construct of teaching self-efficacy was chosen as the focus of this study. Specifically, we attempted to develop an engineering teaching self-efficacy instrument to measure teachers' engineering teaching efficacy.

Self-efficacy is broadly defined as one's perceived capabilities to successfully perform an action. This construct is grounded in Bandura's social cognitive theory which posits that self-efficacy beliefs motivate individuals to take specific actions necessary to achieve a goal and that this construct could be used as a variable to make predictions about one's future behaviors (Bandura, 1977). Bandura proposed that behavior is based on two factors: outcome expectancy and self-efficacy expectancy. He described efficacy expectancy as a belief about an individual's capability to achieve a desired outcome and outcome expectancy as a belief of individuals about the outcome as a result of their behaviors.

Many scholars applied Bandura's construct of self-efficacy to teachers and teaching context. In this strand, Tschannen-Moran et al. (1998) described teaching self-efficacy as "teacher's belief in his or her own capability to organize and execute courses of action required to successfully accomplish a specific teaching task in a particular context" (p. 233). Tschannen-Moran et al. suggested a model explaining that teaching self-efficacy is shaped by the interaction between the examining of personal teaching capabilities and of teaching practices in the context. The resulting self-efficacy beliefs affect teachers' instructional decisions and classroom practices. Studies have long been providing empirical support for the link between self-efficacy and teachers' classroom behaviors in terms of motivation, efforts, enthusiasm and student outcomes (e.g., Bandura, 1997; Woolfolk, Rosoff, & Hoy, 1990).

Several self-efficacy scales were developed over the past two decades based on Bandura's social cognitive theory. Gibson and Dembo (1984) developed an instrument to examine the two sub-constructs of teaching efficacy which were labelled as personal teaching efficacy and general teaching efficacy. Building on the work of Gibson and Dembo, Riggs and Enochs (1990) developed a context-specific instrument -the Science Teaching Efficacy Belief Instrument (STEBI) to examine the efficacy of teaching science. Based on the responses of 331 practicing elementary teachers to the scale, a principal components factor analysis yielded two-factor solution: The Personal Science Teaching Efficacy (PSTE) scale and the Science Teaching Outcome Expectancy (STOE) scale. The PSTE scale includes 13 items assessing teachers' perceived ability to find ways to teach science effectively, explain science concepts and integrate scientific experiments. The STOE scale consists of 12 items measuring teachers' perceptions about the effectiveness of their science teaching on students' achievements. Cronbach's alpha coefficient of internal consistency for the PSTE scale was found to be .92 and for the STOE scale was found to be .77. In this study, following Riggs and Enochs's work, we attempted to develop and validate engineering teaching self-efficacy instrument to measure elementary teachers' engineering teaching efficacy.

Recently, Yoon et al. (2014) who voiced the lack of an instrument to examine teachers' engineering teaching self-efficacy, developed a scale to measure K-12 teachers' engineering teaching efficacy. They adapted the several self-efficacy instruments to develop Teaching Engineering Self-Efficacy Scale (TESS). However, in their study, Yoon et al. pointed out that the consistency of the validity of the scale was not tested across grade levels (for elementary, middle and high school teachers). Therefore, in response to Bandura's proposal that self-efficacy is a situation-specific construct, we developed a valid and reliable engineering teaching self-efficacy instrument for elementary teachers through modifying Riggs and Enochs's (1990) STEBI.

Procedure

Participants

The participants included 197 in-service elementary teachers from a large urban school district in the Southwestern United States. The participants ranged in age from 24 to 65 years with a mean of 42.1 years. Their teaching experience ranged from 1 to 40 years, and they had taken several college-level science courses ranged from 1 to 10.

Instrument

The items of the Science Teaching Efficacy Belief Instrument Version A (STEBI-A) (Riggs & Enochs, 1990) were modified to develop the Engineering Teaching Efficacy Belief Instrument (ETEBI). The original ETEBI consists of 25 items designed on a 5-point Likert type scale ranging from strongly disagree (1) to strongly agree (5). The sample items include "I know the steps necessary to teach engineering design concepts effectively." and "I do not know what to do to turn students on to engineering." Besides, additional data were collected concerning previous engineering professional development program/workshop experience, the choice of teaching engineering, and opinions on the devotion of the time to teach engineering to be used for validity assessments.

Data Analysis and Findings

We employed an exploratory factor analysis with varimax rotation to determine the factor structure of the ETEBI through using SPSS version 25.0. First, the strength of relationship among the variables and sampling adequacy of the data were examined to check the applicability of factor analysis on the data. The Bartlett's test of sphericity yielded statistically significant value ($\chi 2 = 2442.003$, $p< .05$) and the Kaiser-Meyer-Olkin (KMO)'s measure of sampling adequacy was found to be high (.896), verifying the applicability of further analysis.

Given the correlations between factors do not exceed .32, the varimax rotation was used in this study. The results of the varimax rotation were portrayed in Table 1. The factor loadings demonstrate how strong each item is influenced by the principal component; eigenvalues show the amount of variance explained by each principal component and the cumulative variance indicated the percent of the total variance explained by principal components. Only items with factor loading exceeding .50 on their designated scale with communality value greater than .40 were retained. Of the 25 items, two reverse items (Item 10: "The low performance of some students on engineering design projects cannot generally be blamed on their teachers." and item

13: “Increased effort in engineering teaching produces little change in some students’ engineering achievement.”) loaded on a third factor. The literature suggested that each factor or subscale should include at least three items to establish the factor stability (e.g., Tabachnick & Fidell, 1996). Therefore, these two items were dropped from further interpretation. Besides, four items (Item 20: “Effectiveness in engineering teaching has little influence on the achievement of students with low motivation”, item 21: “Given a choice, I would not invite the principal to evaluate my engineering design teaching.”, item 23: “When teaching engineering, I usually welcome student questions.” and item 25: Even teachers with good engineering teaching abilities cannot help some kids learn engineering) were cross-loaded on two components with the loading of > 0.4 and thus, were removed. The rest of the items loaded at .611 or higher on their target factor (see Table 1). The eigenvalue for each factor was greater than 1 as suggested by Kaiser (1960) and the cumulative variance for both principal components was high at 56.83. Given that items loaded on factors were aligned with those found in Riggs and Enochs’s (1990) study, we labeled two subscales as personal engineering teaching efficacy (PETE) and engineering teaching outcome expectancy (ETOE).

Table 1. *Final factor loadings, eigenvalues, and percentage of variance for the ETEBI*

	Factor Loadings	
Item	PETE	ETOE
Item 12	.845	
Item 5	.813	
Item 22	.811	
Item 24	.796	
Item 18	.759	
Item 19	.759	
Item 2	.728	
Item 6	.709	
Item 8	.665	
Item 17	.639	
Item 3	.611	
Item 15		.812
Item 4		.780
Item 14		.754
Item 7		.743
Item 16		.742
Item 11		.709
Item 1		.707
Item 9		.707
Eigenvalue	6.21	4.58
% Variance	32.69	24.14
Cumulative % variance	32.69	56.83

The final ETEBI consists of 19 items with 11 items on the PETE subscale and 8 items on the ETOE subscale. Possible scores on the PETE subscale range from 11 to 55 and ETOE scores may range from 8 to 40. The Cronbach alpha coefficient was used to determine internal consistency reliability for each subscale. Cohen et al. (2000) suggested that alpha be at least .70 or higher for an ‘adequate’ scale and a lenient cut-off of be .80 required for a ‘good’ scale. Reliability analysis indicated the alpha coefficient for both subscales were above .80 (Table 2).

In addition to analysis of the factorial structure of the scale, this study addressed the construct validity of the scale. It is necessary to confirm the validity of a scale by using more than one method consisting of using psychometric techniques (Kind, Jones & Barmby, 2007). Therefore, this study examined the discriminant, convergent, concurrent, and predictive validity of the scale. The factor loadings and internal consistency measures demonstrated the high correlation among items on each subscale which, therefore, verified the convergent validity of the ETEBI instrument. In terms of discriminant validity examining the extent to which factors are correlated, Field (2009) suggested that there be a strong correlation among items within a factor. However, factor correlations should not exceed .85. The correlation matrix indicated that the highest correlation between items was .82, verifying the discriminant validity.

Table 2. *Internal consistency reliability (Cronbach alpha) and the ability of the ETEBI sub-scales to differentiate between classes (ANOVA results)*

Scale	Number of items	Cronbach alpha	ANOVA results (Eta^2)
PETE	11	.919	.287*
ETOE	7	.885	.025*

*p<.05

Concurrent validity, referring to the ability of the scale to differentiate between classes, was calculated by using ANOVA eta^2. The teachers were asked whether they had participated in engineering PD and/or workshops before. Given that learning experiences have an impact on self-efficacy beliefs (e.g., Palmer, 2006), our scales should be able to differentiate between the scores of teachers who had engineering experience and of those who did not. As shown in Table 2, eta^2 values for each component was found to be statistically significant ($p < .05$), which means that each subscale in the ETEBI differentiated significantly between different classes, and thus, confirm the concurrent validity of the ETEBI subscales.

The predictive validity was explored by investigating the ability of the scales to predict teachers' choice of teaching engineering and opinions on the devotion of the time to teach engineering. It was confirmed that teachers' choice of teaching science and opinions on the devotion of the time to teach science were correlated with personal and outcome expectancy (Riggs & Enochs, 1990). In this study, we modified these two variables by replacing science with engineering. The correlations between ordinal variables were performed by using Spearman non-parametric analysis. The analyses revealed that both scales were significantly correlated with these two variables (see Table 3).

Table 3. *Spearman correlations between the ETEBI subscales and two variables*

Variables	PETE subscale	ETOE subscale
Choice to teach engineering	.605**	.143*
Devotion of the time to teach engineering	.306**	.15*

*p<.05 **p<.01

The Contribution of the Study to the Teaching and Learning of Science

As a strong variable of predicting teachers' classroom practices, teaching self-efficacy has been an important construct in teacher education. Building on the work of Riggs and Enochs (1990), this study aimed to develop a valid and reliable engineering teaching self-efficacy belief instrument to measure elementary teachers' efficacy beliefs. As a content and grade level specific instrument, the use of the ETEBI could contribute to the literature on engineering education. Given that learners' conceptions are starting to shape at the elementary level, it is important to lay a strong foundation for engineering education at this early level. For this reason, elementary teachers should be prepared to meet this demand. However, bearing in mind that research on K-12 engineering education is still an emerging area, our knowledge about elementary teachers' implementations of recent standards is limited. In this regard, the ETEBI instrument could be useful in identifying elementary teachers' self-efficacy systems and provide a further understanding of their classroom implementations regarding engineering education.

The Contribution of the Study to the interests of NARST members

Researchers could use the ETEBI instrument to investigate the current status of teachers' teaching self-efficacy beliefs which also provide insight into teachers' behaviors in the classroom. Also, the ETEBI instrument could be used as an assessment tool by PD or workshop providers to examine the effects of their programs on elementary teachers' engineering teaching self-efficacy beliefs. The assessment of engineering teaching efficacy could also highlight the areas that need improvements so that trainers could adjust their programs accordingly by addressing those areas.

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