AC 2012-4413: DEVELOPMENT OF THE TEACHING ENGINEERING SELF-EFFICACY SCALE (TESS) FOR K-12 TEACHERS

Dr. So Yoon Yoon, Purdue University, West Lafayette

So Yoon Yoon, is a Postdoctoral Researcher at INSPIRE in Purdue University. She received her Ph.D. in educational psychology with specialty in gifted education and holds a B.S. degree in astronomy and meteorology and two master's degrees in astronomy and astrophysics and research methods and measurement. Her work centers on development and validation of instruments, particularly useful for P-16 STEM education settings and investigation of P-16 students' spatial ability to understand its association with their academic performance and to identify their talents in STEM fields.

Mr. Miles Griffin Evans,
Dr. Johannes Strobel, Purdue University, West Lafayette

Johannes Strobel is Director of INSPIRE, Institute for P-12 Engineering Research and Learning and Assistant Professor of engineering education and learning design and technology at Purdue University. NSF and several private foundations fund his research. His research and teaching focuses on policy of P-12 engineering, how to support teachers and students' academic achievements through engineering learning, the measurement and support of change of "habits of mind," particularly in regards to sustainability and the use of cyber-infrastructure to sensitively and resourcefully provide access to and support learning of complexity.

Development of the Teaching Engineering Self-Efficacy Scale (TESS) for K-12 Teachers

To teach engineering in K-12 classrooms means, for most teachers, to teach something for which they are not adequately prepared: pre-service teacher training does not require learning engineering and there are no teaching licenses for engineering teaching[1]. There is, however, a large movement to provide in-service teachers with professional development to help them integrate engineering into their classrooms[2,3]. A well-established construct to measure teachers' preparedness and effect on students' achievement is "teacher self-efficacy towards teaching", which can be defined as the personal belief of teachers in their abilities to positively affect students' educational attainments[4]. For example, teachers' self-efficacy in teaching mathematics, or the lack thereof, significantly impacts students' attainment in mathematics[5]. Thus, an instrument to measure teacher self-efficacy towards teaching is context and domain-specific[4]. In order to adequately address needs of teachers and to evaluate the success of teacher professional development programs for K-12 Engineering, an instrument for teaching engineering self-efficacy needs to be developed and rigorously tested.

Theoretical Framework

Self-efficacy is one's personal belief about his or her capability to take an action toward an attainment[6]. Since the introduction of self-efficacy in Bandura's (1977)[4] theory of social learning, self-efficacy has been an important measure in education. Particularly, teacher self-efficacy has received attention from researchers because of findings that indicate its direct relationship with teachers' classroom behaviors that influence the student performance[7,8,9]. For example, Gibson and Dembo (1984)[8] revealed differences in classroom behavior between high-efficacy and low-efficacy teachers. While low-efficacy teachers spent a lot of time in small group instruction, high-efficacy teachers spent more time in whole group instruction, monitoring and checking seatwork, and preparation. In addition, high-efficacy teachers provided more praise per correct answer and less criticism per incorrect answer than low-efficacy teachers. High-efficacy teachers also guided students to correct answers effectively through more questioning. Thus, high-efficacy teachers devoted more effort to teaching students, and did so with better instructional strategies than low-efficacy teachers.

As a consequence of the relationship between teachers' self-efficacy and their commitment in class, some researchers showed how students' psychological states were affected by teacher self-efficacy[10,11]. Midgley, Feldlaufer, and Eccles (1989)[11], in a two year longitudinal study, showed how students' belief about their mathematical ability can change depending on the level of self-efficacy of the teachers about teaching mathematics. Students who were taught by high-efficacy teachers in elementary schools showed significantly lower levels of expectancy and performance in middle school when they had low-efficacy middle school teachers. In addition, the drop in psychological states of low achieving students was bigger than high achieving students. The results indicate how much teachers' self-efficacy influences students' psychological states and their performance in class.

While reviewing studies on teachers' self-efficacy, Tschannen-Moran, Woolfolk Hoy, and Hoy (1998)[12] conceptualized a framework to clarify the confusion around teacher self-efficacy. The framework outlines a cognitive procedure in the formation of teacher self-efficacy, which is cyclical in nature (See Figure 1). Rooted on Bandura's (1986)[13] four sources of self-efficacy (verbal persuasion, vicarious experience, physiological arousal, and mastery experience), the interaction between teachers' analysis of a teaching task and assessment of teaching competence results in their self-efficacy that shapes their personal goals, amount of effort, and level of persistence in teaching students. Therefore, teachers' performance in class is affected by their teaching self-efficacy, and, in turn, the outcome of their performance becomes the foundation of new sources of self-efficacy. Through this cycle, teacher self-efficacy is developed and changed. Here, note that teachers' appraisal of the task and of their competence level of teaching differ by subject and environment, so that teacher self-efficacy is subject to vary by the context.

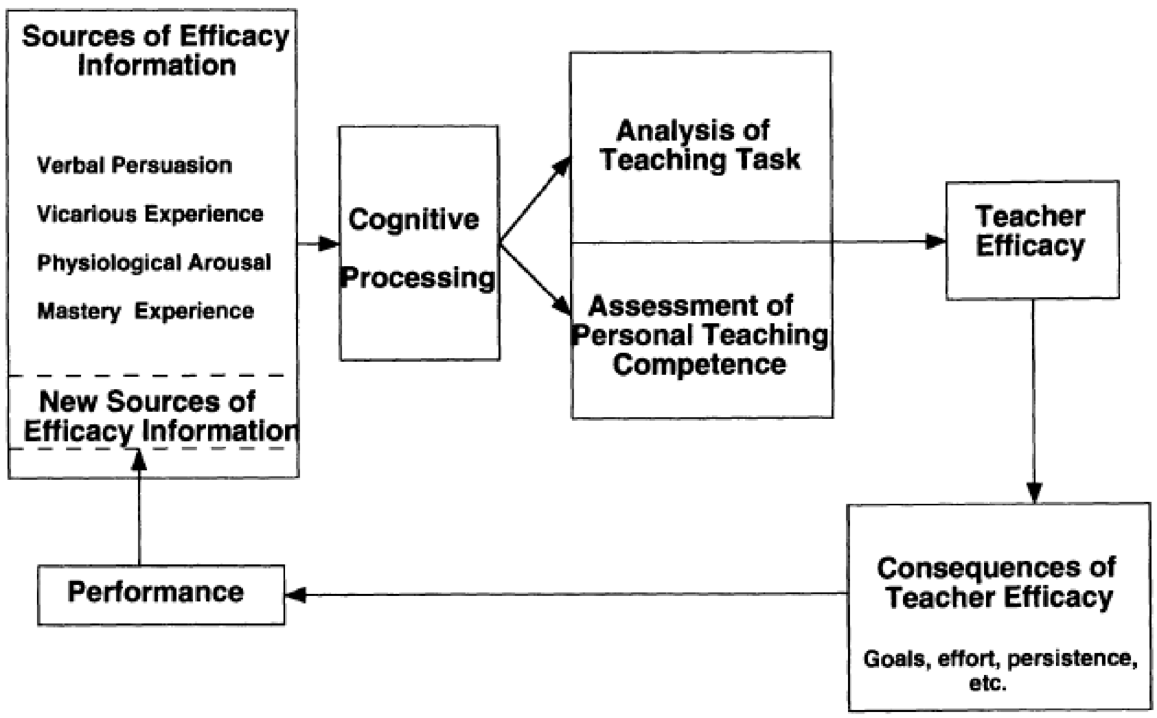

Figure 1. Framework of the teacher self-efficacy formation by Tschannen-Moran, Woolfolk Hoy, and Hoy (1998, p. 228)[12]

The literature provided enough evidence that perceived self-efficacy by teachers plays a critical role in the functionality of classroom dynamics between teachers and students. Teacher self-efficacy is not only related to their behavior in class, but also to goals, aspirations, and outcome expectancy toward their students, meaning that teacher self-efficacy holds great influence on students' self-efficacy, motivation, and achievement[4,12]. In other words, teachers' self-efficacy moderates teachers' commitment and predicts student outcomes.

Several teacher self-efficacy instruments have been developed, validated, and utilized for various purposes in education[14]. In the beginning, only general aspects of teacher self-efficacy were considered, targeting all grade level of teachers without discrimination between subject areas[8,11]. Facing a lack of specificity in teaching situations of different subject areas, Riggs and Enochs (1990)[15] limited the content area of their instruments to the teaching of science and the grade level of teachers to elementary. Their Science Teaching Efficacy Belief Instrument (STEBI) was designed to measure two constructs, outcome expectancy and self-efficacy. The two constructs were based on Bandura's theoretical framework that behaviors are effected by both personal expectancy about the outcome and personal belief about teaching. The specific content area of teaching, which is science, was to reflect the fact that teacher self-efficacy can vary depending on the content area. For example, while some teachers have high self-efficacy in teaching language arts, they may not have the same level of self-efficacy in teaching science.

Since the first development of the STEBI, with its increasing use in science education, several variants of the STEBI were also developed and tested in the specific content areas, targeting different populations. For example, self-efficacy instruments in teaching mathematics for pre-service teachers[16], chemistry for middle school teachers[17], microcomputer utilization for in-service teachers[18], and STEM education for graduate teaching assistants[19] are rooted in the STEBI. Even though those instruments were established based on the STEBI, the types of constructs, the total number of items, and phrasing of the statements in each item were tailored to fit the content and population targeted in each instrument. These modifications were necessary because an instrument that measures teacher self-efficacy needs enough sensitivity to catch the self-efficacy situated in particular teaching contexts.

Reviewing more than ten major teacher self-efficacy instruments in the literature, Tschannen-Moran, Woolfolk Hoy, and Hoy (1998)[12] noted that most instruments were generally designed to assess global aspects of self-efficacy, so they might not be useful tools to provide enough practical information. Thus, an optimal level of specificity was necessary to make certain what is being measured in the instrument. In their later study, Tschannen-Moran and Hoy (2001)[14] pointed out several problems of currently available instruments of teacher self-efficacy: First, validity and reliability of the instruments were still questionable. Second, the two-factor structure of common teacher self-efficacy instruments was controversial because of the possibility of missing other aspects of self-efficacy, which naturally has many facets. Third, a question arose about the level of specificity in the given contexts because it was hard to discern to what extent self-efficacy instruments need to be generalizable across different contexts.

Teacher self-efficacy in the contexts of teaching science, mathematics, and technology has been investigated in various studies. However, teachers' beliefs have rarely been explored in the setting of K-12 engineering education, since engineering was introduced into pre-college programs. Considering the fact that engineering is a new genre for teachers who have been never exposed to it for teaching, teachers must deal with content, materials, and teaching styles different from other subjects when conducting engineering activities[20]. Thus, teacher training is a necessary prerequisite for the effective teaching of engineering. Under these circumstances, many professional development programs that teamed up university professors and graduate students have been developed and applied for teachers to be qualified and confident in teaching engineering[21].

Although recent efforts have been focused on teacher education, there has been no credible instrument developed to measure teachers' self-efficacy in teaching engineering. Therefore, development of a particular instrument to assess the teachers' belief is essential for research in K-12 engineering education so that the measure can serve to clarify the belief system of teachers who will teach engineering in class and/or who already integrated engineering into their curricula. As a result, the measure will be beneficial for researchers and practitioners who are involved in teacher education programs, and will provide teachers with suitable programs to increase their efficacy in teaching engineering in the first place.

Purpose of the Study

Since engineering was introduced in K-12 education[22], there has been a dire need to develop an instrument to measure teachers' self-efficacy situated in the context of teaching engineering. Thus, this study reports the development and validation procedures of the teachers' teaching engineering self-efficacy scale (TESS). For this study, engineering teaching self-efficacy was defined as teachers' personal belief in their ability to positively affect students' learning of engineering. Because "there is no all-purpose of measure of perceived self-efficacy"[23], we planned to include various aspects of engineering in the context of teaching. Therefore, TESS contains aspects of engineering design, teamwork, connection to other subjects, and discipline issues in hands-on engineering activities. In short, we aim to tailor the TESS to tap into the multifaceted nature of self-efficacy and engineering. By exploring the responses on the TESS, we can reveal the dynamics between teachers and students when engineering education occurs in the classroom.

Method

Instrument Development

Under the guidance of the literature about scale development and psychometric testing procedures[24], particularly focusing on self-efficacy instruments[12, 23], we undertook several steps to develop an instrument to measure teachers' self-efficacy in teaching engineering. First, we reviewed studies that reported developmental processes of teacher self-efficacy instruments and that used those instruments in the literature. The teacher self-efficacy instruments considered in the study included Teacher Efficacy Scale[8], Science Teaching Efficacy Belief Instrument (STEBI)[15], Bandura's (2006)[23] Teacher Self-efficacy Scale, Ohio State Teacher Efficacy Scale (OSTES)[14], and Teaching Technology Self-efficacy[25]. Table 1 shows more information about the instruments in terms of the number of items, the level of the scale, and the constructs that the instruments are designed to measure. Studies using those instruments provided an idea of possible factor structures for the TESS.

Table 1. Teaching Self-efficacy Instruments in the Literature

Author	Instrument	N. of Items	Scale	Constructs
Gibson & Dembo (1984)[8]	Teacher Efficacy Scale	16	6-point Likert type scale	• Personal teaching efficacy • General teaching efficacy
Riggs & Enochs	Science Teaching Efficacy Belief	25	5-point Likert	• Personal science teaching efficacy (PSTE)

(1990)[15]	Instrument (STEBI)		type scale	• Science teaching outcome expectancy (STOE)
Bandura (2006)[23]	Bandura's Teacher Self-efficacy Scale	30	9-point Likert type scale	• Instructional self-efficacy • Disciplinary efficacy • Influence on decision making • Influence on School resources • Enlisting parental involvement • Enlisting community involvement • Creating a positive school climate
Tschannen-Moran & Hoy (2001)[14]	Ohio State Teacher Efficacy Scale	24	9-point Likert type scale	• Efficacy for instructional Strategies • Efficacy for classroom management • Efficacy for student engagement
Teo (2009)[25]	Teaching Technology Self-efficacy	16	7-point Likert type scale	• Basic teaching skills • Advanced teaching skills • Technology for pedagogy • Traditional use of technology • Constructivist use of technology

Note. Authors were ordered by the year of publication.

Second, we reviewed the literature about the professional development for K-12 teachers' engineering education [26, 27]. This approach helped establish factors and refine items so that the TESS would be situated in an engineering teaching context. Initial items and factors were modeled in detail after the reviewed instruments. Among the various factors that appeared in the teacher self-efficacy instruments in the literature, five factors were considered for inclusion: engineering knowledge, instructional, engagement, disciplinary self-efficacy, and outcome expectancy (See Table 2 for definition of each construct).

Table 2. Five Factors that constitute the Teaching Engineering Self-efficacy Scale (TESS)

Construct (Acronym)	Definition
Engineering knowledge Self-efficacy (KS)	Teachers' personal belief in their knowledge of engineering that will be useful in a teaching context.
Instructional Self-efficacy (IS)	Teachers' personal belief in their ability to teach engineering to facilitate student learning
Engagement Self-efficacy (ES)	Teachers' personal belief in their ability to engage students while teaching engineering.
Disciplinary (as in classroom management) Self-efficacy (DS)	Teachers' personal belief in their ability to cope with a wide range of student behaviors during engineering activities.
Outcome Expectancy (OE)	Teachers' personal belief in the effect of teaching on student learning of engineering.

Third, we modified the existing items from the self-efficacy instruments in the literature and also generated new items to be situated in the context of teaching engineering. For consistency and clarification, item redundancies were eliminated and all items were rephrased to be statements, not questions, to be positively worded (e.g., “I can” instead of “I can’t”), and to eliminate inconsistencies in word choice (e.g., “student,” instead of “child”). New items were also added to the initial item pool to fill in gaps, particularly for the engineering knowledge self-efficacy construct, which is a new construct to measure pedagogical and content knowledge for teachers. In total, 128 items under the five factors were generated for the next step of content and face validity survey.

Fourth, all the items in the initial pool were judged by a panel of professors and graduate students in engineering and education disciplines. Fourteen panel members paired each item with a construct and indicated their level of confidence. Each item’s score was the maximum number of people who agreed on a construct-item pairing with a high confidence level. If the scores of an item were relatively high for a specific construct, then those items were kept as possible indicators of the construct. If the scores of an item spread across several constructs with relatively low scores, then those items were discarded, because they might not be a good indicator of one specific construct. Finally, reflecting the review and suggestions by the panel, 68 items were nominated to indicate the five factors.

Fifth, the format of the survey was determined using the suggestions about improvements of teacher self-efficacy instruments for future study in the literature[14, 28]. For example, the level of scale was determined to be a six-point Likert type scale (strongly disagree, moderately disagree, disagree slightly more than agree, agree slightly more than disagree, moderately agree, and strongly agree) for the TESS. The decision was made based on the study by Boone, Townsend, and Staver (2010)[28], who conducted an experiment using the responses on the STEBI. Through reliability and Rasch analyses, they showed that the six-point response option, which does not have any neutral points or uncertainty points in the middle, provided better measurement properties of the instrument than four- or five-point response scales.

Sample and Procedure

For the scaling procedures of the TESS, we targeted K-12 teachers as population of the TESS. Qualtrics, which is web-based survey software, was used to construct the instrument online. Then, teachers who were in K-12 education and who intended to incorporate engineering or already incorporated engineering into their classrooms were invited via email to participate in the research and asked to respond to the TESS online. They were also requested to fill out an online background survey to report their demographic information. Table 3 delineates the demographic information of the 153 participants in fourteen states (CA, CT, FL, IL, IN, LA, MA, MD, NJ, NY, OH, PA, TX, and VA). 63 teachers (41.2%) had an expereince of attending a professional development program related to K-12 engineering education before. Their age ranged from 22 to 67 with a mean of 45.7 and a standard deviation of 10.6. Eight teachers did not respond on age. On average, the surveys took around 12 minutes to complete.

Table 3. Demographic Information of 153 Participants

	N^*	%
Gender*		
Female	91	59.5
Male	60	41.2
Race/Ethnicity		
Hispanic	3	1.9
American Indian or Alaska Native	2	1.3
Asian	4	2.5
Black	8	5.1
Native Hawaiian or other Pacific Islander	0	0.0
White	131	82.9
Multi-racial	4	2.5
Age		
30 years or less	14	8.9
31 ~ 40 years	39	25.5
41 ~ 50 years	41	26.8
51 ~ 60 years	42	27.5
More than 60 years	10	6.5
Full Time Teaching Experience		
5 years or less	25	16.3
6 ~ 10 years	33	21.6
11 ~ 20 years	57	37.3
21 ~ 30 years	23	15.0
31 ~ 40 years	13	8.5
Teaching Grade Level		
Elementary School (K ~ 5)	47	30.7
Middle School (G6 ~ G8)	35	22.9
High School (G9 ~ G12)	67	43.8
Total	153	100.0

Note. *Due to unspecified responses, the numbers are inconsistent with the total participant numbers.

Data Analysis

An exploratory factor analysis (EFA) was conducted with the data from 153 teachers to investigate underlying factor structures of the instrument and to identify irrelevant items that do not fit into any factors. The distribution of responses on six-point Likert scale for each item was skewed and did not follow a normal distribution, so the estimation of the parameters using the maximum likelihood (ML) estimator, which assumes a normal distribution of responses, was not applicable. Thus, the data were treated as categorical data, which are ordered and non-normal. The framework to conduct an EFA with categorical data differs from the one with continuous data, so robust weighted least squares (WLSMV) was utilized as an estimator to obtain parameter estimates of the factor analysis. The EFA was completed using the Mplus 6.0 program[29] that optimally estimates a factor structure of the underlying latent variables of the categorical data[30]. The EFA was carried out by the calculation of polychoric correlation coefficients, eigenvalues, and factor loadings after oblique rotation of GEOMIN, which is the default rotation of the Mplus. After the identification of the factor structure of the TESS, the reliability coefficient of internal consistency, Cronbach's α, was calculated for each factor to investigate how items are interrelated within the factor.

Results

Factor Extraction and Factor Loadings

Since the data are ordered categorical variables, polychoric correlation coefficients among the 68 items were calculated. The correlation matrix indicated that the coefficients were all positively correlated, meaning that putative factors identified through an EFA are not independent. In addition, no multicollinearity (strong correlations over .85) existed between two or more items, implying that no items measure the same thing of the constructs and each item contributes to unique aspects of the factors. Several criteria exist to extract the number of factors underlying the data: the point of inflexion of the curve in the scree plot[31] and the number of eigenvalues greater than one[32]. Following Kaiser (1960)'s criteria[32], we retained factors with eigenvalues greater than one. Thus, seven factors were considered for the possible number of factors of the TESS. Since a putative factor structure of the TESS is identified, the factor loadings of the items for each factor were gauged to decide which items constitute which factors. Based on Stevens' (2002)[33] guideline about the relationship between the sample size and cutoff factor loading, items with a factor loading greater than .40 were considered significant for the designated factor. Thus, the cutoff criterion of factor loading functions to suppress irrelevant items that do not fit well into the designated factor. However, if an item loaded onto more than one factor, then the item was excluded because this indicates that the item has relationship with more than one factor. There were no items loaded onto the seventh factor greater than the cutoff value of factor loading, so the seventh factor was not included for the factor structure of the TESS. This resulted in 41 items, out of the original 68, that fit into one of the six factors, as shown in Table 4. All 41 items had significant factor loadings onto one of six factors, indicating each item's unique contribution to one of the factors.

Table 4. Exploratory Factor Analysis Results for the TESS (N = 153)

		Rotated Factor Loadings					
		1	2	3	4	5	6
Engineering Pedagogical Content Knowledge Self-efficacy							
1	I can explain the different aspects of the engineering design process.	1.059*					
2	I can discuss how given criteria affect the outcome of an engineering design project.	1.028*					
3	I can explain engineering concepts well enough to be effective in teaching engineering.	0.996					
4	I can assess my students' engineering design products.	0.974					
5	I know how to teach engineering concepts effectively.	0.939					
6	I can teach engineering as well as I do most subjects.	0.907					
7	I can craft good questions about engineering for my students.	0.902					

8	I can employ engineering activities in my classroom effectively.	0.839					
9	I can discuss how engineering is connected to my daily life.	0.819					
10	I can spend the time necessary to plan engineering lessons for my class.	0.808					
11	I can explain the ways that engineering is used in the world.	0.775					
12	I can describe the process of engineering design.	0.757					
13	I can select appropriate materials for engineering activities.	0.721					
14	I can create engineering activities at the appropriate level for my students.	0.702					
15	I can stay current in my knowledge of engineering.	0.694					
16	I can recognize and appreciate the engineering concepts in all subject areas.	0.650					
17	I can guide my students' solution development with the engineering design process.	0.632					
Motivational Self-efficacy							
18	I can motivate students who show low interest in learning engineering.		0.755				
19	I can increase students' interest in learning engineering.		0.661				
20	Through engineering activities, I can make students enjoy the class more.		0.444				
Instructional Self-efficacy							
21	I can use a variety of assessment strategies for teaching engineering.			0.740			
22	I can adequately assign my students to work at group activities like engineering design.			0.702			
23	I can plan engineering lessons based on each student's learning level.			0.681			
24	I can gauge student comprehension of the engineering materials that I have taught.			0.679			
25	I can help my students apply their engineering knowledge to real world situations.			0.550			
Engagement Self-efficacy							
26	I can promote a positive attitude toward engineering learning in my students.				0.690		
27	I can encourage my students to think creatively during engineering activities and lessons.				0.596		
28	I can encourage my students to think critically when practicing engineering.				0.517		
29	I can encourage my students to interact with each other when participating engineering activities.				0.498		
Disciplinary Self-efficacy							
30	I can control disruptive behavior in my classroom during engineering activities.					0.896	
31	I can keep a few problem students from ruining an entire engineering lesson.					0.889	
32	I can redirect defiant students during engineering lessons.					0.868	
33	I can calm a student who is disruptive or noisy during engineering activities.					0.789	
34	I can get through to students with behavior problems while teaching engineering.					0.569	
35	I can establish a classroom management system for engineering activities.					0.542	
Outcome Expectancy							
36	I am generally responsible for my students' achievements in engineering.						0.638
37	When my students do better than usual in engineering, it is often because I exerted a little extra effort.						0.625

38	My effectiveness in engineering teaching can influence the achievement of students with low motivation.	0.505
39	When a student gets a better grade in engineering than he/she usually gets, it is often because I found better ways of teaching that student.	0.502
40	If I increase my effort in engineering teaching, I see significant change in students' engineering achievement.	0.471
41	I am responsible for my students' competence in engineering.	0.436

Note. *If categorical data are employed to indicate the latent factor structures, then factor loadings correspond to probit regression coefficients when WLSMV is employed. Thus, factor loadings greater than one are possible values.

Table 4 shows that the first 17 items clustered on Factor 1 related to the construct regarding teachers' belief in engineering knowledge and teaching (self-efficacy in engineering pedagogical content knowledge). The three items on Factor 2 were associated with teachers' belief to motivate students' engineering learning (motivational self-efficacy). Factor 3 with five items related to teachers' belief in various aspects of instructional strategies (instructional self-efficacy). Factor 4 with four items represents teachers' belief to engage students (engagement self-efficacy). Factor 5 with six items appeared to be the disciplinary self-efficacy component. Finally, the last six items loaded on Factor 6 aggregated to be the component of outcome expectancy.

Measures of Reliability

The overall reliability of the TESS with 41 items was Cronbach's α = .979 from N = 153. Each construct housed in the TESS appeared to have good internal consistency as shown in Table 5. All items were worthy of retention because removal of any item for each factor would not increase Cronbach's α.

Table 5. Internal Consistency Reliability Coefficients of the TESS

Factor	1	2	3	4	5	6
Construct (Acronym)	Engineering pedagogical content knowledge Self-efficacy (PS)	Motivational Self-efficacy (MS)	Instructional Self-efficacy (IS)	Engagement Self-efficacy (ES)	Disciplinary Self-efficacy (DS)	Outcome Expectancy (OE)
N. of Items	17	3	5	4	6	6
Cronbach's α	.977	.837	.923	.880	.936	.877

Discussion and Conclusion

This study aimed to develop and validate the TESS to measure K-12 teachers' self-efficacy in teaching engineering. To do this, we identified possible five factors to represent various aspects of the self-efficacy (engineering knowledge, instructional, engagement, outcome expectancy, and disciplinary self-efficacy) through the literature review and generated items to fit well with the constructs through the content and face validity survey. However, the EFA with the data from 153 teachers resulted in six factors (engineering pedagogical content knowledge, motivational, instructional, engagement, disciplinary, and outcome expectancy) significantly indicated by 41 items. The items, which were generated for self-efficacy in disciplinary and outcome expectancy, were extracted to represent each construct. However, the items for engagement self-efficacy were disaggregated into two constructs. Thus, they were renamed motivational and engagement self-efficacy, respectively. In addition, the items created to represent engineering knowledge and instructional self-efficacy became clustered to indicate one construct (named as engineering pedagogical content knowledge self-efficacy). However, some items generated for instructional self-efficacy did not merge to represent engineering pedagogical knowledge self-efficacy and clustered together indicate one distinct construct as we intended (named as instructional self-efficacy). In summary, through the EFA, the factor structure of the TESS was identified to have six factors and the items constructed for the TESS were restructured and tailored to fit well into the six constructs.

Limitation and Future Study

Science and mathematics have a long history in the K-12 schooling system and are well integrated into the preparation and continuous training of teachers. Similarly, the many concepts of science and mathematics are shared amongst educators. Engineering in K-12 is yet to be fully conceptualized[1, 34], which does not only impact practice of teaching engineering in K-12 but has larger impacts for this study. A limitation of this study is that it presumes a definition of engineering, which might not be shared by all members of the community and not shared by all participants of the study. Our comprehensive literature review addresses some of the concerns, yet future research on the impact of different conceptualizations of engineering in K-12 and their impact on teachers' self-efficacy is necessary.

The target population for the use of the TESS is the K-12 teachers in the United States. However, the sample for this study consists of the teachers in fourteen states. Thus, the result of this study has limitation in generalizability to make inferences beyond the sample characteristics of this study. In addition, the sample size of this study was marginal to conduct an EFA. Thus, the results based on the EFA may not be fairly reliable representation of the factor structure of the TESS. Thus, a CFA will warrant finalization of the items and factor structure of the TESS. Therefore, a confirmatory factor analysis (CFA) is planned to be applied with a new data set from over 200 teachers. In addition, item analyses based on classical test theory and item response theory will follow to evaluate overall psychometric properties of the newly developed instrument. Since the TESS consists of measures of several constructs on the six-point Likert scale, the MULTILOG 7.0 program[35] will be employed for the analysis of ordered polytomous data. Additional evaluations of validity, such as convergent, discriminant, concurrent, and predictive, are the planned following steps for a future study.

Significance of the Study

Teacher self-efficacy is a situation specific construct because teacher efficacy beliefs depend on the content area and teaching environment[4]. Thus, the use of the TESS, as a teacher self-efficacy instrument tailored for the engineering teaching context, is expected to contribute to the literature for K-12 engineering education. First, the TESS can easily serve to diagnose and clarify the teacher's self-efficacy system and to further understand teachers' behavior in class. Second, when preparation of teachers occurs through in-service, pre-service, or professional development programs, the instrument allows researchers to examine how teachers initiate their own beliefs, attitudes, and behavior patterns in the beginning of the programs and shape them throughout the programs. Thus, the TESS can be used as one indicator for evaluation of teacher preparation programs. Third, after diagnosing the current status of teachers' self-efficacy, the measure will be beneficial to figure out the best approaches to increase self-efficacy of teachers depending on their weak area of the constructs. For example, when teaching engineering, low-efficacy teachers in instructional strategies may need different approaches in training to enhance their belief from low-efficacy teachers in disciplinary issues. Fourth, research using the TESS can extend the investigation of the relationship between teachers' self-efficacy and students' achievement situated in teaching and learning engineering, while considering other plausible factors that may affect teachers' behavior in class and students' performance in engineering. In conclusion, we expect that the TESS can lead to diverse approaches in research on K-12 engineering education.

Bibliography

1. Katehi, L., Pearson, G., & Feder, M. (Eds.). (2009). *Engineering in K-12 education: Understanding the status and improving the prospects* (Committee on K-12 Engineering Education, National Academy of Engineering and National Research Council). Washington, DC: National Academies Press.
2. Capobianco, B. M., Diefes-Dux, H. A., & Mena, I. B. (2011, June). *Elementary school teachers' attempts at integrating engineering design: Transformation or assimilation?* Paper presented at the 2011 American Society of Engineering Education Annual Conference, Vancouver, Canada.
3. Cunningham, C. M., Lachapelle, C. P., & Keenan, K. (2010). *Elementary teachers' changing ideas about STEM and STEM pedagogy through interaction with a pedagogically supportive STEM curriculum*. Paper presented at the K-12 Engineering and Design Education Research Summit, Seaside, OR.
4. Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: Freeman.
5. Borko, H., & Whitcomb, J. A. (2008). Teachers, teaching, and teacher education: Comments of the National Mathematics Advisory Panel's Report. *Educational Researcher*, 37, 565- 572. doi:10.3102/0013189X08328877
6. Bandura, A. (1977). *Social learning theory.* Englewood Cliffs, NJ: Prentice Hall.
7. Coladarci, T. (1992). Teachers' sense of efficacy and commitment to teaching. *Journal of Experimental Education, 60,* 323-337.
8. Gibson, S., & Dembo, M. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology, 76, 569-582.*
9. Muijs, D., & Reynolds, D. (2002). Teachers' beliefs and behaviors: What really matters. *Journal of Classroom Interaction, 37,* 3-15.
10. Ashton, P. T., & Webb, R. B. (1986). *Making a difference: Teachers' sense of efficacy and student achievement.* New York: Longman.
11. Midgley, C., Feldlaufer, H., & Eccles, J. S. (1989). Change in teacher efficacy and student self- and task-related beliefs in mathematics during the transition to junior high school. *Journal of Educational Psychology, 81,* 247–258.
12. Tschannen-Moran, M., Woolfolk Hoy, A., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, *68*, 202-248.
13. Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, NJ: Prentice-Hall.
14. Tschannen-Moran, M., & Woolfolk Hoy, A. (2001). Teacher efficacy: Capturing and elusive construct. *Teaching and Teacher Education, 17,* 783-805.

15. Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, *74*, 625-637.
16. Enochs, L. G., Smith, P. L., & Huinker, D. (2000). Establishing factorial validity of the Mathematics Teaching Efficacy Beliefs Instrument. *School Science and Mathematics, 100, 194–202.*
17. Rubeck, M. E., & Enochs, E. G. (1991, April). *A path analytical model of variables that influence science and chemistry teaching self-efficacy and outcome expectancy in middle school science teachers*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Fontana, WI.
18. Enochs, L. G., Riggs, I. M., & Ellis, J. D. (1993). The development and partial validation of microcomputer utilization in teaching efficacy beliefs instrument in science setting. School Science and Mathematics, 93, 257-263.
19. DeChenne, S. E., & Enochs, L. (2010, April). *Measuring the teaching self-efficacy of science, technology, engineering, and math graduate teaching assistants.* Paper presented at the 2010 American Educational Research Association annual conference, Denver, CO.
20. Rogers, C., & Portsmore, M. (2004). Bringing engineering to elementary school, *Journal of STEM Education : Innovations and Research*, *5*, 17-28.
21. Jeffers, A. T., Safferman, A. G., & Safferman, S. I. (2004). Understanding K–12 engineering outreach programs. *Journal of Professional Issues in Engineering Education and Practice, 130*, 95-108.
22. Mathias-Riegel, B. (2001). Engineering that's elementary. *Prism, 10*(7), 34-36.
23. Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajares & T. Urdan (Eds.), *Adolescence and education, Vol. 5: Self-efficacy beliefs of adolescents* (pp. 307–337).
24. Netemeyer, R. G., Bearden, W. O., & Sharma, S. (2003). *Scaling procedures*. Thousand Oaks, California: Sage Publications, Inc.
25. Teo, T. (2009). Examining the relationship between student teachers' self-efficacy beliefs and their intended uses of technology for teaching: A structural equation modeling approach. *The Turkish Online Journal of Educational Technology*, *8*(4), 7-16.
26. Capobianco, B. M. (2011). Exploring a science teacher's uncertainty with integrating engineering design: An action research study. *Journal of Science Teacher Education*, 22, 645-660. doi:10.1007/s10972-010-9203-2
27. Duncan, D., Diefes-Dux, H. A. & Gentry, M. (2011). Professional development through engineering academies: An examination of elementary teacher recognition and understanding of engineering. *Journal of Engineering Education, 100*, 520-539.
28 . Boone, W. J., Townsend, J. S., & Staver, J. (2010). Using Rasch theory to guide the practice of survey development and survey data analysis in science education and to inform science reform efforts: An exemplar utilizing STEBI self-efficacy data. *Science Education*, *95*, 258-280. doi: 10.1002/sce.20413
29. Muthén, L. K., & Muthén, B. O. (1998-2010). *Mplus User's Guide*. 6th Ed. Los Angeles, CA: Muthén & Muthén.
30. Brown, T. A. (2006). *Confirmatory factor analysis for applied research*. New York, NY: Guilford Press.
31. Cattell, R. B. (1966). The scree test for the number of factors. *Multivariate Behavioral Research*, *1*, 245-276.
32. Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, *20*, 141-151.
33. Stevens, J. P. (2002). *Applied multivariate statistics for the social sciences* (4^{th} ed.). Hilsdale, NJ: Erlbaum.
34. National Academy of Engineering. (2010). *Standards for K-12 engineering education?* Washington, DC: National Academies Press. Retrieved from http://www.nap.edu/openbook.php?record_id=12990
35. Thissen, D., Chen, W-H., & Bock, R. D. (2003). *MULTILOG 7 for Windows: Multiplecategory item analysis and test scoring using item response theory* [Computer software]. Lincolnwood, IL: Scientific Software International, Inc.