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## **AC 2011-2243: USING FACTOR ANALYSIS TO RE-VISIT THE TEACHING DESIGN, ENGINEERING, AND TECHNOLOGY (DET) SURVEY**

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# Using Factor Analysis to Re-visit the Teaching Design, Engineering, and Technology (DET) Survey

## Background and Theoretical Framework

In recent years there had been an increased focus on teaching engineering in K-12 schools. The demand for training K-12 teachers in engineering education is likely to increase considering the proposed changes in the National Science Education Standards<sup>1</sup>. There also has been an increased interest in using appropriate methodologies to develop valid and reliable instruments in engineering education research. High quality assessment tools with sound psychometric properties can ensure the meaning of the score inferences from the instruments; thus, provide researchers and administrators with valuable information.

An example of a commonly used assessment instrument is the design, engineering, and technology (DET) survey. DET is a four-point Likert scale instrument designed by Yasar and her colleagues<sup>2</sup> to measure K-12 teachers' perceptions of and familiarity with engineering. Since 2006, this self-reported instrument has been used by many researchers to gain critical information regarding K-12 teachers' perception of engineering and their familiarity with teaching DET<sup>3,4,5</sup>. This information has been used to provide a foundation for effective professional development for K-12 teachers as well as counselors.

Instrument development is an iterative process that requires continued efforts to ensure the psychometric soundness (e.g., reliability and validity) of the instrument when applied to various populations and settings. Hence, the re-evaluation of existing instruments is common. Examples of such psychometric re-evaluation studies can be found in counseling<sup>6</sup>, marketing<sup>7</sup>, gerontology<sup>8</sup>, and organizational research<sup>9</sup>. Such research enables the collection of further psychometric evidence of previously developed instruments and helps refine the factor structure of instruments for generalizability.

Reliability is an index that estimates consistency and dependability of test scores. It is about whether people maintain their position in the score distribution over times or equivalent test forms. Validity deals with what the test is supposed to measure and how well it does this job. As described in the *Standards for Educational and Psychological Testing*<sup>10</sup>, validity "refers to the degree to which evidence and theory support the interpretations of test scores entailed by proposed uses of tests" (p. 9). In validity study, the exploratory factor analysis (EFA) is often used to downsize a large set of observed variables, and determine the latent dimensionality of them. It is normally used to discover the latent factor(s) that determines the inter-correlations among the observed variables. For instance, in psychology, general intelligence is believed to be composed of two factors: the fluid and crystallized intelligence. Under each factor, observed variables or items were developed to measure these unseen (or latent) factors.

The purpose of this study is to re-evaluate the psychometric soundness of the DET survey using new data collected from a larger and a relatively more diverse group of elementary

teachers. Specifically, we aimed at obtaining further psychometric evidence of the DET instrument by conducting the EFA to refine the factor structure due to variations in sample size and population characteristics. The reliability estimate (i.e. the Cronbach's Alpha,) of the refined instrument was also reported.

## Method

### *Instrumentation*

Since 2006, the DET survey has been used to gain critical information regarding K-12 teachers' perceptions of engineering and their familiarity with teaching DET<sup>3,4,5</sup>. The data collected through the DET survey has been used to provide a foundation for effective professional development for K-12 teachers. DET is one of the few instruments used in pre-college engineering education settings with moderate psychometric evidence (e.g., reliability and validity) verified in the paper by Yasar et al. in 2006. Further evaluation of this instrument will benefit educators and their efforts to immerse engineering into K-12 curricula.

### *Participants*

The DET instrument was taken by 405 elementary teachers, who attended a teacher professional program between 2006 and 2010. Table 1 shows the detailed composition of the sample across four background variables: gender, ethnicity, years of teaching and survey format. Among these respondents, 88% were females, while 12% were males. Approximately 36 percent of them had no more than five years of teaching experience, while 40 percent had six to fifteen years and 24 percent had more than fifteen years of experience. Caucasian teachers dominated the sample with 82 percent, as compared to the 18 percent of non-Caucasians.

Table 1. *Composition of the sample*

| Category          | Sub-category     | N   |
|-------------------|------------------|-----|
| Gender            | Male             | 50  |
|                   | Female           | 355 |
| Ethnicity         | Caucasians/White | 332 |
|                   | Minority         | 73  |
| Years of Teaching | Less than 6      | 146 |
|                   | Between 6 and 15 | 161 |
|                   | Greater than 15  | 98  |
| Survey Format     | Paper-pencil     | 124 |
|                   | Online           | 281 |
| Total             |                  | 405 |

### *Data Analysis*

When conducting EFA, the Maximum Likelihood (ML) was used as the main parameter

estimation method. When judging how many factors should be extracted, we analyzed the Eigen values and cumulative variance explained by the factor solution. For more information about how to conduct EFA, please see Gorsuch<sup>11</sup>. We also collected the reliability estimates (i.e., the Cronbach's Alpha), as well as the reliability estimates after each individual item was deleted.

### Results

Using the new sample, the results of EFA conducted on the DET instrument supported a four-factor solution similar to Yasar, et al<sup>2</sup>, although the composition of the factors was different. Table 2 presents the summary of the composition difference. Specifically, the four items originally from the *Familiarity with DET* factor (i.e., items 35-38), as well as two items previously from the *Stereotypical Characteristics of Engineers* factor (e.g., items 39 and 40), should form a new factor. In addition, item 18 was found uncorrelated with most of the four factors, thus it was flagged as a potential irrelevant item. After consulting with the content experts and further investigation, this item was dropped from the EFA analysis. Finally, item 19, which originally was in the *Characteristics of Engineering* factor, was found to be correlated more with the *Importance of DET* factor.

Based on these findings, we proposed that for the current study the name of the new factor will be *Barriers in Integrating DET*, which contains items 35-38, as well as items 39 and 40. Also, items previously from the *Characteristics of Engineering* factor will merge into the *Characteristics of Engineers* factor.

Table 2. *Summary of Items that Changed Their Factor*

| <b>Items that Contributed to the Change of the Final Factor Solution</b>      | <b>Previous Factor</b>                     | <b>Current Factor</b>       |
|---|--|-----------------------------|
| 18. How important should pre-service education be for teaching DET?           | Importance of DET                          | Dropped                     |
| 19. DET has positive consequences for society                                 | Characteristics of Engineering             | Importance of DET           |
| 35. Barrier in integrating DET - lack of teacher knowledge                    | Familiarity with DET                       | Barriers in Integrating DET |
| 36. Barrier in integrating DET - lack of training                             | Familiarity with DET                       | Barriers in Integrating DET |
| 37. Barrier in integrating DET - lack of time for teachers to learn about DET | Familiarity with DET                       | Barriers in Integrating DET |
| 38. Barrier in integrating DET - lack of administration support               | Familiarity with DET                       | Barriers in Integrating DET |
| 39. Most people feel that minority students can do well in DET                | Stereotypical Characteristics of Engineers | Barriers in Integrating DET |
| 40. Most people feel that female students can do well in DET                  | Stereotypical Characteristics of Engineers | Barriers in Integrating DET |

Table 3 presents the EFA results that include the final factor solution and factor loading

for each item.

Table 3. *Final factor solution with factor loading for each item*

| <b>Factor 1: Importance of DET</b>   | <b>Factor Loadings</b> |
|--|------------------------|
| 1. I would like to be able to teach my students to understand the use and impact of DET                                | 0.82                   |
| 2. I would like to be able to teach my students to understand the science underlying DET                               | 0.77                   |
| 3. I would like to be able to teach my students to understand the design process                                       | 0.77                   |
| 4. I would like to be able to teach students to understand the types of problems to which DET can be applied           | 0.81                   |
| 5. My motivation for teaching science is to promote an understanding of how DET affects society                        | 0.61                   |
| 6. I am interested in learning more about DET through in-service   | 0.62                   |
| 7. I would like to be able to teach students to understand the process of communicating technical information          | 0.73                   |
| 8. My motivation for teaching science is to prepare young people for the world of work                                 | 0.49                   |
| 9. My motivation for teaching science is to promote an enjoyment of learning   | 0.52                   |
| 10. I believe DET should be integrated into the K-12 curriculum  | 0.53                   |
| 11. I am interested in learning more about DET through workshops   | 0.68                   |
| 12. I am interested in learning more about DET through college courses   | 0.34                   |
| 13. In a science curriculum, it is important to include the use of engineering in developing new technologies          | 0.48                   |
| 14. I am interested to learning more about DET through peer training   | 0.54                   |
| 15. My motivation for teaching science is to help students develop an understanding of the technical world             | 0.56                   |
| 16. My motivation for teaching science is to educate scientists, engineers and technologists for industry              | 0.56                   |
| 17. In a science curriculum, it is important to include planning of a project  | 0.47                   |
| 18. How important should pre-service education be for teaching DET?  | 0.38                   |
| 19. DET has positive consequences for society  | 0.50                   |
| <hr/>  |                        |
| <b>Factor 2: Familiarity with DET</b>  |                        |
| 20. How familiar are you with DET?   | 0.66                   |
| 21. Have you had any specific DET courses outside of your pre-service curriculum?                                      | 0.48                   |
| 22. How confident do you feel about integrating more DET into your curriculum?   | 0.56                   |
| 23. Was your pre-service curriculum effective in supporting your ability to teach DET at the beginning of your career? | 0.68                   |
| 24. Did your pre-service curriculum include any aspects of DET?  | 0.61                   |
| 25. I use DET activities in the classroom  | 0.69                   |
| 26. I know the national science standards related to DET   | 0.43                   |
| 27. My school supports DET activities  | 0.43                   |
| <hr/>  |                        |
| <b>Factor 3: Characteristics of Engineers</b>  |                        |
| 28. A typical engineer has good verbal skills  | 0.50                   |
| 29. A typical engineer works well with people  | 0.47                   |
| 30. A typical engineer has good writing skills   | 0.57                   |
| 31. A typical engineer does well in science  | 0.63                   |
| 32. A typical engineer has good math skills  | 0.52                   |
| 33. A typical engineer earns good money  | 0.47                   |
| 34. A typical engineer likes to fix things   | 0.59                   |
| <hr/>  |                        |
| <b>Factor 4: Barriers in Integrating DET</b>   |                        |
| 35. Barrier in integrating DET - lack of teacher knowledge   | 0.47                   |
| 36. Barrier in integrating DET - lack of training  | 0.52                   |
| 37. Barrier in integrating DET - lack of time for teachers to learn about DET  | 0.30                   |
| 38. Barrier in integrating DET - lack of administration support  | 0.23                   |
| 39. Most people feel that minority students can do well in DET   | 0.45                   |
| 40. Most people feel that female students can do well in DET   | 0.45                   |

Factor loading is the standardized regression coefficient between each item and the factor. High factor loading is desired, because it means a strong correlation or bonding between the factor and the items. For instance, the factor loading of item 1 is 0.82, which

means the standardized correlation between item 1 and factor 1 is 0.82. More importantly, it also indicates that approximately 67% ( $0.82 \times 0.82$ ) of item 1's variance was associated with factor 1. Items are presented in the same order as they shown in Yasar et al.<sup>2</sup> except for the adjustments mentioned above.

The refined four-factor solution explained approximately 74 percent of the total variance as a total. This means that the new factor structure did a better job explaining the total variances in observed variables compared to the total of 43 percent in the previous study. Specifically, the *Importance of DET* factor accounted for 39 percent of the total variance while the *Familiarity with DET* factor accounted for 17 percent of the total variance. In addition, the *Stereotypical Characteristics of Engineers* factor and *Barriers in Integrating DET* factor explained 10 percent and 8 percent of the total variance, respectively.

Table 4 reports the factor-level descriptive statistics and reliability estimates for each factor for the refined factor structure, which is the part of the item analysis. The means and medians for each scale were roughly equal, indicating teachers' scores on each factor were approximately normally distributed. As shown in the table, the Cronbach's alpha of the *Stereotypical Characteristics of Engineers* factor and *Barriers in Integrating DET* factor were a little low, indicating relatively weak internal consistence among scores. However, the other two factors had better reliability evidence and the overall reliability is acceptable.

Table 4. *Descriptive statistics and reliability estimates of the refined DET factors*

| <b>Factor/Subscale</b>                        | <b>Number<br/>of<br/>Items</b> | <b>Alpha</b> | <b>Mean</b> | <b>Median</b> |
|---|--------------------------------|--------------|-------------|---------------|
| Importance of DET                             | 19                             | 0.91         | 65.31       | 66            |
| Familiarity with DET                          | 8                              | 0.81         | 15.59       | 15            |
| Stereotypical Characteristics of<br>Engineers | 7                              | 0.77         | 23.82       | 24            |
| Barriers in Integrating DET                   | 6                              | 0.68         | 16.87       | 17            |
| Total   | 40                             | 0.88         | 121.60      | 122           |

*Note.* Alpha=overall Cronbach's Alpha

When we analyzed results at an item-level, we found that most of the teachers disagreed with the content of item 21 stating whether they had DET experiences outside of their pre-service curriculum with a mean of 1.28 out of 4 (see Table 5). Same conclusion can be drawn for item 23 (i.e., Was your pre-service curriculum effective in supporting your ability to teach DET at the beginning of your career?), item 24 (i.e., Did your pre-service curriculum include any aspects of DET?), and item 26 (i.e., I know the national science standards related to DET) that have item means below two. The remaining thirty six items have a mean above two, indicating that teachers agreed with the content of each question.

The sample item analysis results also provided what the overall reliability estimate would

be if a specific item was deleted. It was not surprising to see an increased internal consistency reliability estimate with the deletion of item 37 to 40. The reason is that all of these four items had low item-total correlations, which inevitably hurt the overall reliability estimate.

Table 5. *Sample item analysis results*

| Sample Items   | Mean (SD)   | Item-Total Correlation | Alpha |
|--|-------------|------------------------|-------|
| 21. Have you had any specific DET courses outside of your pre-service curriculum?                                      | 1.28 (0.60) | 0.31                   | 0.86  |
| 23. Was your pre-service curriculum effective in supporting your ability to teach DET at the beginning of your career? | 1.48 (0.74) | 0.22                   | 0.86  |
| 24. Did your pre-service curriculum include any aspects of DET?  | 1.54 (0.78) | 0.20                   | 0.86  |
| 26. I know the national science standards related to DET   | 1.97 (0.89) | 0.27                   | 0.86  |
| 37. Barrier in integrating DET - lack of time for teachers to learn about DET  | 3.13 (0.82) | 0.07                   | 0.86  |
| 38. Barrier in integrating DET - lack of administration support  | 2.06 (0.99) | 0.02                   | 0.87  |
| 39. Most people feel that minority students can do well in DET   | 2.78 (0.69) | 0.21                   | 0.86  |
| 40. Most people feel that female students can do well in DET   | 2.72 (0.70) | 0.21                   | 0.86  |

*Note: SD=standard deviation, Alpha=what the overall coefficient alpha (0.88) would be when this item is deleted.*

### Discussion

The main purpose of this study was to validate and refine the DET instrument to ensure it is conceptually and empirically consistent with the latent construct defined in the prior study. Our study highlights the importance of a continuous evaluation of instruments in engineering education especially considering the changing populations of teachers and the increasing emphasis on engineering education in K-12 classrooms.

We used EFA as the main methodology to identify and refine the factor structure using the new sample. Our hope is that this study will be an exemplar for other similar validation studies. Research in engineering education requires robust instruments with strong validity evidence. For the refined DET instrument, we did find acceptable reliability evidence for each factor and overall factor structure, ranging from .77 to .91. All these findings provide researchers with a fairly strong empirical basis for the use of the refined DET. For future research, a larger sample size needs to be collected to validate the revised factor structure. Overall, compared to other alternatives with no or little psychometric evidence in engineering education, DET is still a strong theory-based instrument with a promisingly stable and robust factor structure. Further research on confirmatory factor analysis is needed.

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