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TEACHERS' PERCEPTIONS STRUCTURED THROUGH FACET THEORY: SMALLEST SPACE ANALYSIS VERSUS FACTOR ANALYSIS

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This article examines Guttman's facet theory (FT) and compares it to factor analysis (FA) in the context of two research studies. FT is examined in terms of its advantages and disadvantages compared to FA for theory development and confirmation. Two studies provide insights into the utility of FT. The first describes ideal student traits as perceived by prospective teachers. Using FT and smallest space analysis (SSA) confirmed the theory by displaying the accord between the facets in the mapping sentence and the distribution of the items in a multidimensional space. The second describes teacher professionalism and teaching context as perceived by teachers who completed a version of the Talbert and McLaughlin questionnaire. FT and SSA confirmed the theory and identified the subscales and dynamic relationships between them. By using the definitional mapping sentence of FT and SSA, the multidimensional theory and structural validity of the findings in the two studies were confirmed.

Several approaches to dealing with data for theories of structure exist. Factor analysis (FA) is one commonly used approach in which a number of

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variables are reduced into factors that are considered components of the theoretical structure. FA may or may not be used within a theoretical framework. Smallest space analysis (SSA), also known as structural similarity analysis, is another approach to analyzing structure. One of the benefits of using SSA is that it is typically used within the framework of Guttman's facet theory (FT) (Canter, 1985; Guttman, 1954, 1957, 1965, 1982a; Guttman & Levy, 1991; Levy, 1994). FT is a method for the design of studies, providing a set of principles for the prediction of structures in the actual empirical observations, and selecting appropriate data analyses giving a philosophical basis to the nature of empirical research in the social sciences (Borg & Shye, 1995).

A number of articles (e.g., Edmundson, Koch, & Silverman, 1993) have presented the FT approach in research without demonstrating its utility relative to other approaches such as FA. Schwartz and colleagues (Schwartz, 1992, 1995; Schwartz & Bilsky, 1990) have performed cross-cultural studies to test the value structure of teachers and university students. Benyamini and Limor (1995) reexamined the results of 45 studies on the perception of ideal characteristics of a role-player by a complementary role-player in terms of Guttman's FT. Their aim was to develop a cumulative theory. Other studies compare the utility of SSA and exploratory FA (Guttman, 1982b; Levin, Montag, & Comrey, 1983; Schlesinger & Guttman, 1969; Schwartz, 1992).

Although the advantages of FT and SSA are well-known to the methodological community, they have not been applied extensively in educational research in the United States. This article analyzes the use of FT for data analysis within the context of two research studies. The FT approach including SSA is compared to FA for both of the studies.

FT

Guttman defines a theory as a hypothesis of a correspondence between a definitional system for a universe of observations and an aspect of the empirical structure of those observations, together with a rationale for such a hypothesis (Levy, 1994). The theory is written as a relation among facets. The form that Guttman developed for the definition of the observations is the mapping sentence. FT includes the fundamental assumption that there is lawfulness that stems from the definition of the observations and their empirical correlations. Thus, empirical analysis of a set of variables can be used to study the facets.

The facet approach may best be described as a research strategy consisting of four aspects: two stages related to theoretical aspects and two related to actual field investigation. The stages are (a) the design of the individual facets, (b) the construction of a mapping sentence expressing the composite of all facets and elements within the facets, (c) the construction of appropriate

research instruments, and, accordingly, (d) the application of an appropriate multidimensional statistical technique (e.g., SSA) (Shirom, 1991).

Stage 1

In Stage 1, based on theory, the facets or components of a given construct are defined. A facet can be a modality, a context, or any other determining dimension or set of contents. The individual characteristics in each dimension are called elements. Multiple facets are examined in each analysis; hence, FT deals with multivariate systems.

Stage 2

In Stage 2, the relationships between the facets are hypothesized in the form of a mapping sentence. A mapping sentence "contains a variety of facets. Each facet is one way of classifying the research variables. A properly defined set of *n* facets provides an *n*-way simultaneous classification of variables" (Levy, 1998, p. 302). Levy (1985) claimed that the general hypothesis of FT is that the roles of the facets in a mapping sentence provide a rationale for the hypothesis of a correspondence between the definitions of the mapping sentence and an aspect of the observed distribution of the data. A mapping sentence defines a universe of observations for a theory and involves three kinds of sets: (a) the population whose members are to be classified, (b) the universe of variables that are the criteria for classification, and (c) the range of categories for each variable. Each possible combination of facets and responses is called a "structuple" (Levy, 1985). For example, the case in which Element 1 from Facet A occurs with Element 3 from Facet B and Element 7 from Facet C forms a structuple.

Stage 3

The third stage in FT is designing the research instrument (e.g., the questionnaire, test). Each element of each facet should be represented in the items. The instrument is then administered to a sample of the population.

Stage 4

The fourth stage is to analyze the collected data using a multidimensional technique. Multidimensional scaling includes a number of analytical techniques for understanding the structure or pattern of a matrix and displaying the structure or pattern as a geometrical form (Shepard & Nerlove, 1972). FT takes this approach with the goal of conceptual clarity. SSA is one of the most common techniques of multidimensional scaling. It was developed by

Guttman (1968) as an analytical technique for application to research with FT (Shepard & Nerlove, 1972). Guttman's work focused heavily on the idea that the analytical techniques used to understand data should not be separate from theoretical development. Thus, the statistical technique of SSA is intended for use as a part of the FT approach to research.

SSA maps the location of each item in a multidimensional space. It treats each variable as a point in Euclidian space in such a way that the higher the correlation between two variables, the closer they are in the space (Guttman, 1968). The location of each item is determined by a measure of similarity or dissimilarity to all of the other items. This can be done using relational rankings (*A* is closer to *C* than *B*; *C* is closer to *D* than *A*) or by maintaining ratios of similarity/dissimilarity to distance. Levy (1994) described the empirical aspects of theory as comprising sets of intercorrelations among observations. The emphasis is on structural lawfulness through regional hypotheses based on the relative sizes of the correlations.

Regional hypotheses are associated with geometry of SSA and related to roles that the content facets play in partitioning the SSA space into regions, for example, Radex structure, cylindrical structure, and so forth (Lingoes, 1973).

Comparison of FT and SSA With FA

SSA and exploratory FA share a common purpose: to reduce the number of variables by making parsimonious groupings. In fact, Guttman explained that FA is actually a type of SSA. Guttman (1982b) described six differences between FA and SSA.

First, SSA affords greater flexibility in specifying the allowable functions describing the relationships among variables. In SSA, distances between items are based on the inverse of a relational coefficient so that the larger the coefficient (e.g., Pearson's product-moment correlation) the smaller the distance between the items. A general equation for this is $d_{ij} = f(r_{ij})$, where f is any negatively sloped monotone function. In FA, f is specified as the square root of $2(1 - r_{ij})$.

A second difference between FA and SSA is that SSA represents domains in fewer dimensions, making the results more coherent. Exploratory FA may produce more factors than can be interpreted by researchers. FA produces a large number of dimensions because the technique relies on strict assumptions of linearity. SSA and other forms of multidimensional scaling allow for possible nonlinear (monotone) relationships between variables. As a result, these methods produce a more visualizable representation (Shepard & Nerlove, 1972).

Third, in FA, the product-moment coefficient is corrected for communality as a lower bound estimate of score reliability, whereas in SSA, the similarity coefficient is not adjusted for reliability. FA depends on this correc-

tion for the reduction of dimensions. SSA produces fewer dimensions without "tampering" with diagonals of the correlation matrix (Guttman, 1982b). Like SSA, FA uses a matrix to determine underlying factors or facets of a construct.

Fourth, partly because FA often produces results with many factors, SSA results may be easier to represent in a visual geometric form. Another difference outlined by Guttman refers to the similarity coefficient used in the analysis. In FA, the similarity coefficients (r_{ij}) must be product moments (Guttman, 1982a, 1982b). However, fifth, SSA results may be based on use of monotonically transferred correlation coefficients.

One final, sixth difference relates to sample size. FA requires large sample sizes. The fact that often 10 or more observations for each item are recommended makes FA inappropriate for many studies. In comparison, although a large sample can make the SSA more robust, large sample size is not critical when SSA is used.

SSA and FA Comparisons

In this article, two studies dealing with the perceptions of Israeli teachers and prospective teachers are presented. Both studies used the FT approach with SSA as well as FA to confirm our theories and test the structural validity of scores on the scales.

Example A: Ideal Student Characteristics

The first study (Maslovaty & Sitton, 1997) presents the structure of the ideal high school student's traits as perceived by prospective teachers in two universities. Previous research (Maslovaty, 1997; Maslovaty & Iram, 1997) showed main content factors as constructing traits: high-level thinking, learning habits sociability, religiosity, modernity, and so forth. The trait system of the ideal student was constructed in keeping with educational goals and with two constructivist theories of development, one dealing with cognitive autonomy and the other with social transformation (Richardson, 1997). The analysis was intended to test the role of these theories.

Study design. Student teachers from two universities rated, on a scale from 1 to 5, a list of 19 characteristics that they perceived as describing an ideal student. A total of 203 teachers completed the survey: 113 from University A and 90 from University B. The mapping sentence constructed concerning their perception of the ideal high school student is shown in Figure 1.

SSA. The monotone correlational matrix resulting from the responses of the sample ranged from .95 to .12 with very few low and negative results. This

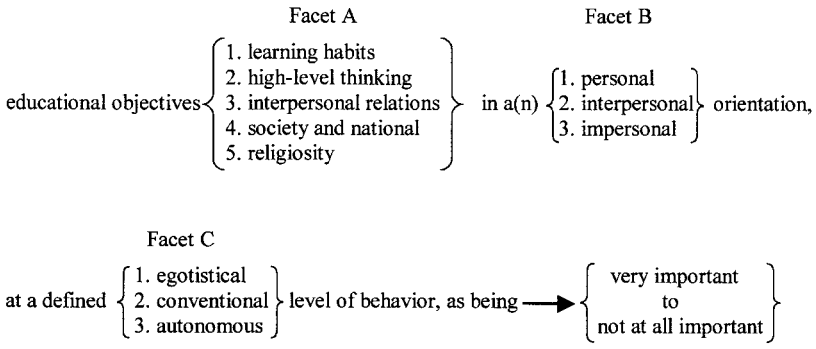

Figure 1. Mapping sentence: The perception of the ideal high school student.

correlational matrix was used to generate graphic two- and three-dimensional geometric correspondences (SSA) that reflect the empirical correlational matrix of the variables. Figure 2 presents a radex graphic display of the interrelationships among the traits of the ideal high school student. The coefficient of alienation in the three-dimensional representation was .14. Facet A, the educational objectives, plays a polarizing role in partitioning the radex space into five regions emanating from one origin. Beginning at the upper part of the circle and proceeding clockwise, the order is as follows: learning skills (three traits), high-level thinking (five traits), interpersonal relationships (six traits), and religiosity (three traits).

A further partitioning according to Facet B, orientation, divided the space into three regions: personal (8 traits), interpersonal (4 traits), and impersonal (5 traits). Facet C, level of behavior, polarized the radex space into two regions: the conventional level of behavior (7 traits) and the autonomous level of behavior (12 traits). All three facets polarized the space. This radex partitioning of the space confirms the structure of the relationships among the traits according to the theories compared.

FA. Table 1 presents the FA varimax-rotated pattern/structure coefficients of the trait system of the ideal high school student as perceived by prospective teachers at the two universities. The analysis yielded five factors from the 19 characteristics.

The first factor included five traits related to society and nation such as "active in social organizations," "participates in national ceremonies," and

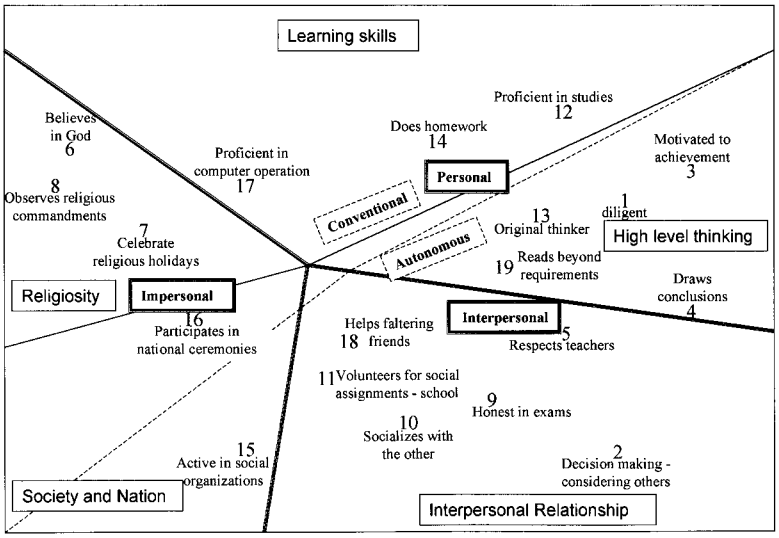

Figure 2. Radex graphic display of the interrelationships among characteristics of the ideal high school student as perceived by prospective teachers.

Note. A two-dimensional projection out of three (coefficient of alienation = .11).

"volunteers for social activities." The second factor included three traits related to religiosity: "believes in God," "observes religious commandments," and so forth. The third factor included traits relating to learning skills such as "diligent" and "does homework." The fourth factor included five traits related to interpersonal relationships such as "makes decisions while showing consideration for others," "respects teachers," and "honest in exams." The fifth factor included two high-level thinking traits such as "reads beyond requirements" and "original thinker." Table 1 presents five factors that correspond to the educational objectives with a number of exceptions; for example, "proficiency in computers" fell into the society and nation factor, and "drawing conclusions" fell into the interpersonal relations factors.

Comparison of results. Comparison of SSA and FA shows that in SSA, all of the traits fell into the exact content constructs as defined by the mapping sentence. The educational objectives facet (Facet A) was confirmed. SSA gave additional information showing the existence of the orientation and level of behavior facets (Facets B and C), which were absent from the FA. Understanding these facets is critical for a comparison of the constructivist theories (Richardson, 1997).

Table 1
Pattern/Structure Coefficients Rotated to the Varimax Criterion: Ideal Student Traits

	Factor				
Characteristic	Society and Nation	Religiosity	Learning Skills	Interpersonal Relations	High-Level Thinking
Active in social organizations	.862	–.064	–.040	.019	–.017
Participates in national ceremonies and events	.805	.246	.076	.030	–.009
Volunteers for social activities at school	.755	.087	.119	.280	.068
Assists faltering friends	.658	.132	.062	.294	.273
Proficient in computer operation	.466	.050	.255	–.210	.202
Believes in God	.046	.927	.009	.007	–.021
Observes religious commandments	.124	.919	–.009	–.023	.039
Celebrates religious holidays	.149	.917	.069	.093	.005
Is diligent and hardworking	.054	–.037	.703	.304	–.083
Endeavors to achieve outstanding results	–.014	–.027	.703	.150	.032
Proficient in the material learned	.043	.069	.692	.084	.229
Does homework	.255	.080	.657	.029	.188
Makes decisions while showing consideration toward others	.031	–.044	.057	.769	.105
Respects his or her teachers	.018	.044	.375	.620	–.107
Honest in exams and work	.203	.073	.190	.584	–.080
Socializes with other people who are different from himself or herself	.483	.110	–.017	.554	.199
Arrives at conclusions based on material learned	–.034	–.059	.335	.456	.371
Reads and is interested in material beyond the curriculum taught	.166	–.003	.130	–.016	.819
Has an original way of thinking	.086	.021	.090	.059	.800

Example B: Teachers' Professional Domains

The second study (Maslovaty, 1997) confirms Talbert and McLaughlin's (1994) theory of teachers' professional domains. Talbert and McLaughlin analyze teacher professionalism as an outcome of collegial interaction in a local school context evolving within active, learning communities of teachers. Systematic variation was found in high school teachers' adherence to

particular professional standards between the multiple-embedded local contexts of teaching: subject area departments, schools, and school districts.

The relationships among teacher community, professionalism, and job satisfaction structured the professional domains in the study (see Facet B in the mapping sentence, Figure 3). The four dependent variables of Talbert and McLaughlin's (1994, p. 134) study correspond to three dimensions of professionalism: (a) the instrumental aspects of teachers' commitment to serving their student clients: technical culture; (b) two indicators of the "service ethic" dimension of professionalism: the personal or affective, caring for students and expectations for students' success represent different facets of the concept that are important to teaching; and (c) the academic or cognitive aspect: professional commitment.

The independent variable for the study was the "teacher community," which included collaboration and ongoing learning among teachers in the school setting. A control variable, "satisfaction with the school," was also identified. According to Talbert and McLaughlin (1994), evidence of tension between a strong service ethic and the technical culture that evolves within some high school departments calls for further research.

Study design. In this study, 92 high school teachers filled out an Israeli version of the Talbert and McLaughlin (1994) teacher professionalism survey. The sample consisted of teachers in the general and religious state education systems who taught three subjects: biology, history, and Bible. The mapping sentence constructed to describe the hypothesis is presented in Figure 3.

SSA. The mapping sentence defined the variables according to three kinds of teachers' professionalism. A monotonicity correlation matrix among the variables was used to generate graphic two-dimensional correspondences. Monotone correlations among the sample ranged from .79 to –.47. Several of the correlations presenting the relationships between questions of caring and technical culture had low negative signs (Questions 9, 10, and 11).

The coefficient of alienation in the three-dimensional representation was .21. However, two of the three dimensions suffice to present the content lawfulness. Figure 4 represents the relationships among the 36 variables. Each question is represented by a point in the map space resulting in a radex with three facets. The elements of the professional area create concentric circles from a point of origin. These modulation partitions correspond to the professional domains presented in Facet B. The innermost circle contains the items dealing with satisfaction. This is surrounded by the teacher community items. Moving outward, the next circle represents professional commitment. Finally, the outermost circle contains the professionalism subscales of care for students, high expectations, and technical culture. Facet C groups the two inner circles together as representing teacher's satisfaction, idea fulfillment, and encouraging experiences. The two outer circles are grouped as represent-

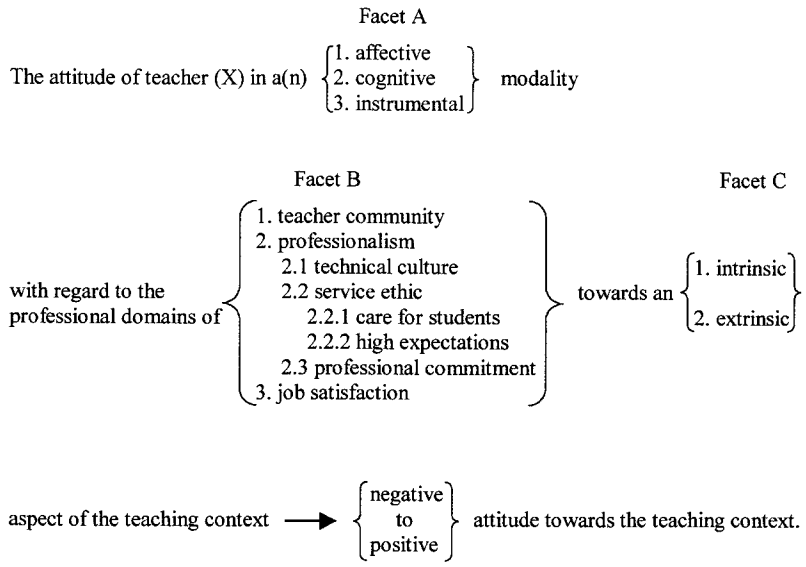

Figure 3. Mapping sentence: teachers' professional domains.

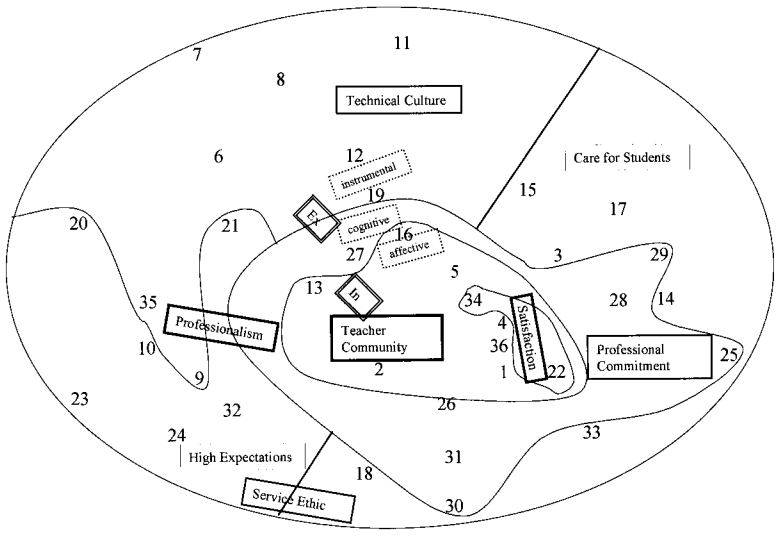

Figure 4. Radex graphic display of the interrelationships among teachers' professional domains.

Note. A two-dimensional projection out of three (coefficient of alienation = .21).

ing the more professional behaviors regarding the policy of teacher education. Dynamic relations among the cycles present the development of the professionalism to domains from outside versus inside from formal to self-fulfillment.

Facet A, which is identified by Talbert and McLaughlin (1994) as representing affective, cognitive, and instrumental modalities, was also confirmed. When the control variable is in the inner circle, the independent variable forms a ring around it. The dependent variables of professional commitment and technical culture are seen in the two outer circles.

FA. Table 2 presents varimax-rotated first 5 factors of the 12 factors extracted by FA. Even the primary factors of the analysis are extremely difficult to interpret, and it is impossible to interpret all 12 of the extracted factors. The 5 factors include only 22 of the variables. An analysis with a limited number of factors was attempted but could not be resolved because of the small sample size.

Comparison of results. The results of both analyses show the advantages of SSA, particularly with a limited sample. Although SSA provided an adequate map showing multiple dimensions of teacher professionalism, the FA furnished a multitude of factors that failed to give insight into the theory.

Discussion

The examples illustrate the utility of FT for theory development and theory validation as well as construction of the scales. The structural hypothesis based on the size of the correlations contributed to the explanation of the results by partitioning the space according to the facets defined in the mapping sentences. In the first example, the region partitioning divided the space according to the three facets—educational objectives, orientation, and level of behavior—enabling to develop a theory by combining ideas from two constructivist theories (Richardson, 1997) in the mapping sentence. The results confirmed previous work (Maslovaty, 1997; Maslovaty & Iram, 1997) creating cumulative knowledge. This multivariate and multifaceted partitioning could not be achieved by FA. In the second example, the modular cycle partitioning divided the space according to three facets—modality, professional domains, and the intrinsic-extrinsic feature. This partitioning confirmed Talbert and McLaughlin's (1994) theory in a different culture, that of Israel. In comparison, the FA yielded 12 uninterpretable factors.

The monotonicity hypothesis defines regressions between two attitude items as being positive or zero; most of the correlations in the two examples were, indeed, positive or zero. The few negative correlations in Example 2 confirm Talbert and Mclaughlin's (1994) findings relating to negative relationships between caring and technical culture.

Table 2
Pattern/Structure Coefficients Rotated to the Varimax Criterion: Teacher Professional Domains

	Factor				
Professional Domain	I	II	III	IV	V
Professional commitment	.748	–.052	.064	.014	.158
Teacher community	.669	.340	.099	.208	–.001
Satisfaction	.653	.281	.256	.338	–.024
Teacher community	.554	.249	.319	.010	–.163
Professional commitment	.540	.333	–.245	–.041	.012
Professional commitment	.534	.028	.222	.026	.098
Teacher community	.510	.023	.337	.298	.317
Professional commitment	.425	.190	.163	–.208	.611
Caring	.101	.751	–.005	.203	.089
Professional commitment	.175	.737	–.608	–.260	.036
Caring	.086	.687	.105	.084	.037
Professional commitment	.185	.669	.204	.075	–.351
Caring	.169	.454	.175	.074	.297
Teacher community	.121	.113	.814	.189	.111
Teacher community	.245	–.031	.689	.013	–.167
Teacher community	.280	.384	.591	–.102	.358
Technical culture	–.116	–.183	.406	.258	–.000
Teacher community	.109	.050	.195	.671	.233
Technical culture	.123	.152	.232	.650	–.076
High expectations	.274	–.062	–.144	.644	.079
Technical culture	.119	–.006	.094	.053	.778
High expectations	.310	–.099	–.173	.050	.507

A comparison of exploratory FA with FT and SSA shows a number of advantages of the latter. In terms of design of the study, FT provides a format that links the theory to the analysis. Through the use of the mapping sentence, the hypothesis is distinctly defined and can be clearly tested. On the other hand, although exploratory FA can be used in conjunction with theory, it often is not.

In addition, SSA performed within the context of FT allows for more flexibility. The choice of coefficients in the matrix submitted for analysis is much greater than in FA and allows for the use of monotonically transformed coefficients. As a result, the output is much easier to interpret. In addition, in SSA, partitioning of items is determined by the researcher and based on theory, whereas in FA, the analysis itself dictates which items fall into which factors, limiting interpretation. This was particularly true in the second example.

Finally, the SSA analysis within FT allows for examination of more components or dimensions of the theory than does FA. This was particularly evi-

dent in the first example. The FA presented five relatively interpretable factors, whereas SSA allowed for examination of these factors as well as additional facets. As has been demonstrated in this article, FT with SSA provides a useful alternative to exploratory FA in educational research.

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