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CONFIRMATORY FACTOR ANALYSIS OF THE QUESTIONNAIRE OF ATTITUDE TOWARD STATISTICAL GRAPHS FOR USE IN SCIENCE EDUCATION

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Abstract. *This study describes the modification of an instrument originally developed for measuring attitudes towards statistical graphs to instead measure elementary pre-service teachers' attitudes towards line graphs in science. As a result of context-modification and in utilizing Confirmatory Factor Analysis (CFA), the finalized instrument comprises 32-items that incorporate constructs of enjoyment, confidence, usefulness and learning preferences. The revised instrument was found to exhibit adequate ranges of internal consistency and reliability. Based on a variety of completed analyses, the revised instrument appears to have maintained original psychometric fidelity and is recommended for use as an assessment of pre-service teachers' attitudes towards line graphs in science.*

Key words: *Confirmatory factor analysis, Line graphing, Pre-service teacher attitudes*

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Introduction

Science education both in the United States and abroad emphasizes the importance of inquiry-based teaching methods. The international science education community acknowledges the importance of such methods (Abd-El-Khalick et al., 2004); underscoring the notion that inquiry should be manifested throughout scientific content taught (Anderson, 2007; National Research Council, [NRC] 1996). It is critical for science teacher educators to address all aspects of this method during the course of instruction. Data communication in science is considered an integral element of inquiry-based teaching and learning because it involves the construction and interpretation of a variety of graphs, tables, charts or visual representations of data (Bowen & Roth, 2005). Roth, McGinn, and Bowen (1998) refer to the visual outcomes typically generated as a result of these types of activities as inscriptions. Graphs in particular, allow for the transformation of data from indistinguishable forms to highly observable representations of phenomena. Another important element related to inquiry-based science teaching and learning involves the study of independent, dependent and control variables. Characteristically, quantitative data is generated and ultimately transposed into some type of graphical form, where the relationship between the variables becomes visually apparent. This process aids in data interpretation and allows for an individual to determine whether there are positive, negative or constant relationships among variables. Specifically, line graphs have been noted as one way to present data between two continuous variables pictorially (McKenzie & Padilla, 1986).

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According to Friel, Curcio, and Bright (2001), line graphs are found to be the dominant type of graph in school curricula, as students begin to learn about the fundamentals associated with line graphs in Kindergarten. As early as grades K-2, students learn the foundations of line graphs by plotting points on a line plot diagram. At grades 3-5 students are introduced to the use of scales in graphing, another fundamental concept. By grades 6-8, students learn about how to organize and present sophisticated and complex data sets. It is at this point where they are formally introduced to line graphing and are expected to compare data sets through the use of such graphs. Much of what students have learned in prior grades augments line graphing. The progression of learning that begins with line plots at the K-2 level is important to the development of line graphing skills students are expected to have by the time they advance to the upper elementary grades. Thus, line graphing is an area that must be well understood by elementary teachers who are teaching science to students throughout grades K-8. In order for teachers to fully understand line graphing and be able to successfully teach students, they must first be taught how to properly construct, comprehend and interpret a graph of this type.

Related studies have investigated pre-service teacher knowledge, skill and amount of practice in regard to graphing in science (Bowen & Roth, 2003, 2005; Lunsford, Melear, Roth, Perkins, & Hickok, 2007; Ritter & Coleman, 1995), where it was determined that pre-service teachers lack the preparation to teach graphing when they become teachers. However, these studies do not address how performance on graphing is associated with attitude towards science, mathematics or graphing. Researchers have maintained the position that both pre-service teachers and students at various levels of education need to improve their graphing knowledge and skills with a substantial amount of practice and more exposure to "authentic" science activities or tasks (Lunsford et al., 2007; Roth & McGinn, 1996). Although this is relevant in terms of cognitive learning associated with graphing, it does not take into account how the attitudes of pre-service teachers could influence graphing performance. The linking of graphing knowledge and skill with attitudinal constructs related in learning has not been addressed thoroughly in that regard. Rather, studies in this area focus on examining and quantifying attitudes towards science (Young, 1998), the impact that methods courses have on pre-service teacher science attitudes and beliefs (Ginns & Foster, 1982; Stefanich & Kelsey, 1989; Tusun, 2000; Palmer, 2001; Yilmaz-Tuzun, 2008), their views regarding pedagogical and mathematical content knowledge (Foss & Kleinsasser, 1996) and how understanding science and their confidence in teaching plays a role in defining self-efficacy (Tekkaya, Cakiroglu, & Ozkan, 2004). Studies examining the interconnectedness of science and mathematics (Bursal & Paznokas, 2006; Cady & Rearden, 2007; Frykholm & Glasson, 2005; Koirala & Bowman, 2003) pay particular attention to the dispositions of pre-service teachers as part of some type of teacher training program or methods course.

The ubiquity of such lines of research have omitted attitudinal aspects that are linked to the knowledge and skill required for graphing and at best have assumed that attitudinal factors are accounted for during instruction, yet make no mention of it. One study has been located that focused chiefly on attitudes toward graphing among pre-service teachers in science education (Mumba, Wilson, Chabalengula, Mejia, & Mbewe, 2009). This study found that pre-service teacher attitudes towards graphs was impartial to positive, suggesting that attitudes were a factor that could hinder the teaching and learning of graphs among teachers. However, an explanation regarding the psychometric development of the instrument that was used to collect data was precursory of general reliabilities. Therefore, a study originating in the United States that contributes to an international body of literature on pre-service teacher attitudes towards line graphing was necessitated because it not only extends the current line of research to include the measurement of a series of attitudinal constructs, but illustrates the straightforwardness and feasibility of a process needed to establish full psychometric validity of the instrument itself.

In order to bridge the gap between what is understood regarding the influence of affect in science with what has been reported in the literature regarding graphing among pre-service teachers, factors such as attitude toward line graphing within science teacher education must be given consideration alongside elements of cognitive performance. This study sought to bring forth a psychometrically sound measure that science educators, both in the United States and worldwide, could use in evaluating attitudinal components pertaining to line graph learning at the pre-service level. The psychometric validation and subsequent use of such an instrument can aid science teacher educators as they inform their instructional decisions regarding the teaching of line graphing in science to pre-service elementary education teachers. If administered in the beginning and at the closing of a semester, one can determine if instructional events are supporting positive attitudes towards the interpretation and creation of line graphs as a result of scientific inquiry. Subsequently, future instruction can be modified so that certain attitudinal elements are fully addressed throughout day-to-day instruction. As science teacher educators move towards improving the teaching of graphing skills and related competencies, they can modify the scope and sequence of both the curriculum and the instruction. First, they can determine which parts of the curriculum should be devoted to the development of specific attributes of attitudes related to interpreting line graphs and graphing data in science. Second, they can emphasize the importance of understanding this aspect of scientific inquiry, as it is much needed and integral in teaching at the in-service level.

Methodology of Research

Sample

Ninety-four pre-service elementary education teachers enrolled in two concurrent elementary science methods courses were administered the revised Questionnaire of Attitude Toward Line Graphs in Science (QALGS). Each course included four and two sections, respectively. The first course emphasized science process skills and inquiry, while the second focused on science content relevant to K-8 teaching. Subjects were drawn from the population of pre-service teachers enrolled in a teacher education program at a Midwestern Research University in the United States. Subjects were between the ages of 20 to 43 years and were selected for participation based on their enrollment in either of the two science methods courses, as well as their willingness to participate. Specifically, there were 77 females and 17 males that comprised the sample, all of who would be teaching general science upon completion of their teacher training.

Instrument Modification

Attitudes of pre-service teachers towards line graphing in science were measured using a context-modified version of the Questionnaire of Attitude toward Statistical Graphs (QASG). The original QASG instrument was developed to investigate the attitudes toward statistical graphs among 907 secondary school students in Singapore. The instrument includes five constructs, namely enjoyment, confidence, usefulness, critical views and learning preferences. The authors reported reliability coefficients of 0.84, 0.79, 0.54, and 0.84 for the constructs of enjoyment, confidence, usefulness and critical views, respectively (Yingkang & Yoong, 2007). A reliability coefficient for the learning preferences construct was not reported. The QASG was chosen because the constructs measured were in close resemblance with factors (excluding critical views) believed to have some type of influence on attitudes toward line graph learning in science. The constructs employed by Yingkang and Yoong's (2007) study are similar to those suggested in Gal and Ginsburg's (1994) study of the roles that attitudes and beliefs have towards statistics. For the purposes of the current study and in relationship to the constructs suggested in past studies, line graphing attitudes are ostensibly influenced by overall interest and motivation – prompting learning (enjoyment) as well as self-efficacy or self-assurance that one could successfully incorporate line graphing into science teaching. Despite its interconnection to mathematics (confidence), readiness to incorporate line graphing in science teaching is primarily concerned with communicating data as a result of scientific-type inquiry (usefulness) and preferences for learning and teaching strategies regarding graphs (learning preferences). The original QASG instrument contains 49 Likert-type questions with a 5-point Likert scale, encompassing strongly disagree, disagree, uncertain, agree and strongly agree. The authors of the QASG did not perform Confirmatory Factor Analysis (CFA) in determining the validity and reliability of the original instrument. The QASG was

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modified to measure elementary pre-service teachers' attitudes towards line graphing in science, where statistical graphs represent line graphs in the context of science rather than bar graphs, pie charts, line graphs, pictograms, dot diagrams, histograms, and other types of graphs typically used in statistics. In particular, thirty-two of the items from the QASG were modified so that statistical graphs and statistics would instead represent line graphs in science and science. The following lists of the original questions found in the QASG:

- When I am asked to read information from a statistical graph;
- When I am asked to give my opinions about an issue based on the data shown in a statistical graph;
- When I am asked to judge whether a statistical graph is correctly constructed or not;
- When I am asked to construct a statistical graph by hand.

Each statement is followed by five sub-statements relevant to its respective base. The constructs measured by the revised QALGS are confidence (C), enjoyment (E), usefulness (U), and learning preferences (LP). The critical views construct was omitted from the revised instrument because it lacked applicability to the context of line graph learning in science.

Data Analysis

CFA was selected as the procedure to test the statistical hypothesis that the factor structure of the QASG would be maintained in the revised QALGS. Specifically, the purpose of this procedure was to examine the extent to which the context modified QALGS instrument did or did not depart from the original QASG instrument. Therefore it was assumed that CFA enables researchers to use knowledge of past theory or empirical research to, "postulate relations between the observed measures and the underlying factors a priori and then test the hypothesized structure statistically" (Byrne, 2001, p. 6). This pre-determined relationship, when confirmed through CFA, allows for steadfastness in instrument validation, thus providing other potential users a valid and reliable measure to use in similar studies.

The latent variable structure of the original QASG, along with a description of its development, was utilized at the time the researcher established testable factor structures for CFA. Thus, each testable measurement model included a main-item statement followed by a series of statements pertaining to that main item. Figures 1-5 illustrate each hypothesized factor structure that was tested as part of this study. Each figure depicts the exogenous (independent) variables, or constructs (unobserved), and endogenous (dependent) variables, or individual items (observed) in the model. Exogenous variables are depicted as ovals; endogenous variables are depicted as rectangles. Inside each rectangle are the associated items for that particular main item (e.g. C1, C3, C5, E2, E4). The small circles to the left of each rectangle are measurement error terms (e.g. err1 – err5) associated with the observed variable – or the particular item in the model. The one-way arrows pointing away from the small circles indicate the random and unique measurement error impact. Directional arrows represent the impact on one variable on another, while double-headed arrows represent correlations between pairs of variables. In the models in this study, the double-headed arrows indicate covariances between the paired exogenous variables. The arrows pointing in the direction of the rectangles are standardized correlation coefficients (Byrne, 2001). Following the establishment of each model structure, Chi-square statistics (primary) were calculated to determine goodness of fit to the sample data. In addition, goodness of fit indices (secondary, supplemental) for each model were calculated as part of the analysis. These indices were analyzed to assist the researcher in determining how well the theoretical constructs of the original instrument matched the actual data of the context-revised instrument.

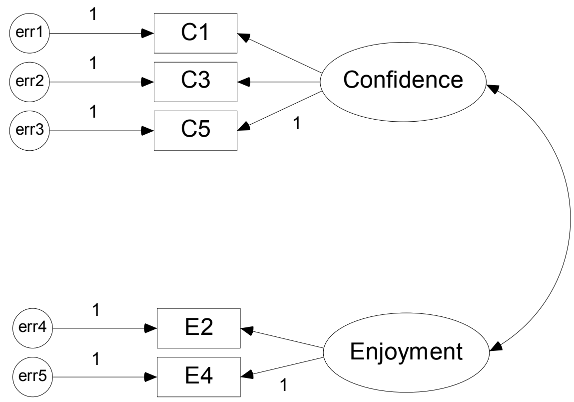

Figure 1: Hypothesized factor structure for first main item: When I am asked to read information from a line graph in science.

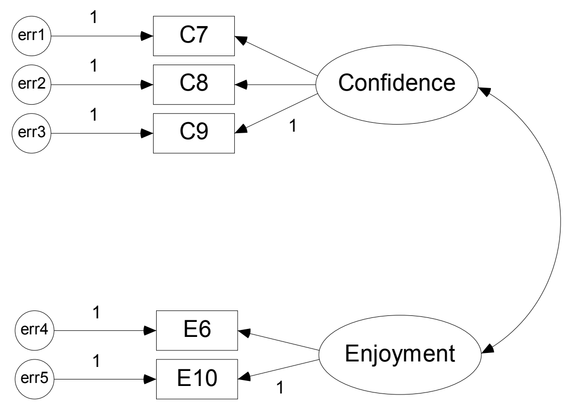

Figure 2: Hypothesized factor structure for second main item: When I am asked to give my opinions about an issue based on the data shown in a line graph in science.

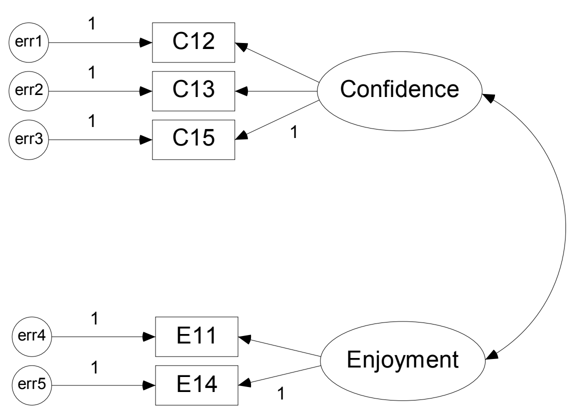

Figure 3: Hypothesized factor structure for third main item: When I am asked to judge whether a line graph in science is correctly constructed or not.

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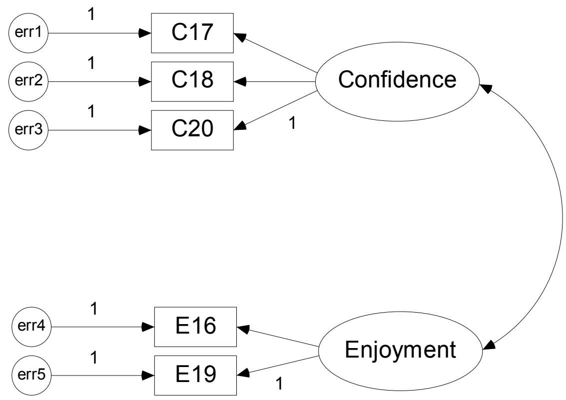

Figure 4: **Hypothesized factor structure for fourth main item: When I am asked to construct a line graph in science by hand.**

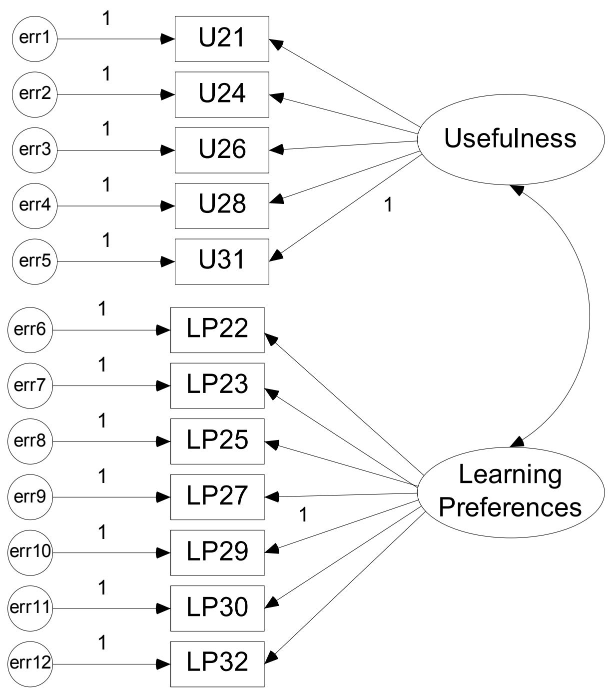

Figure 5: **Hypothesized factor structure for fifth main item: Please indicate the extent of your agreement to each statement.**

Determining Fit of the Measurement Model

In part, classical test theory has been advanced to accommodate the development of new measurement models where there is little or no consensus regarding measured constructs or concepts (Blunch, 2008). This theory is at the crux of establishing reliability for both test scales as well as measurement model items. Establishing reliability for model parameters (e.g. factor loadings and error variances) while using various goodness-of-fit statistics and indices can offer tolerance for some model assumption violations, thus sustaining robustness in the calculated outcome (Reuterberg & Gustafsson, 1992). Under this purview, the researchers in the current study presumed with caution that any differences between contending models would be robust against violations of multivariate normality and linearity among those variables being observed (Jöreskog & Sörbom, 1988).

The Chi-square goodness of fit test supported by a number of goodness of fit indices assisted the researchers in determining the degree of model fit that the revised QALSG instrument had against the original. Using multiple measures of model fit increases the likelihood of showing that hypothesized factor structures are sustained in a revised instrument (Blunch, 2008; Byrne, 2001). Specifically, this study employed the following measures: (1) Chi-square goodness of fit test (Blunch, 2008), with a low statistic indicating good fit. The Chi-square statistic must also be non-significant at the 0.05 level to indicate a good fit. In essence, the Chi-square goodness of fit tests employed in this context-modified instrument development study statistically determine whether there were similarities in observed and expected data set matrices. Typically in a Chi-square goodness of fit test with this purpose, one hopes to find non-significant lower Chi-square values, indicative of congruence between the original and modified instrument. A low Chi-square value reveals little difference between the theoretical model and the current data. On the other hand, achieving statistically significant Chi-square values (higher) indicate non-congruence between observed and expected data set matrices. Ultimately, the Chi-square goodness of fit tests for context-modified instruments are interpreted as tests of dependence, rather than independence; (2) Goodness of fit index [GFI] (Jöreskog & Sörbom, 1984), with values approaching 1 indicating a good fit; (3) Comparative fit index [CFI] (Bentler, 1990), with values approaching 1 indicating a good fit; (4) Root mean square error approximation [RMSEA] (Brown & Cudeck, 1993), with values below 0.05 indicating a good fit, while values of 0.08 are indicative of realistic population errors of approximation – or acceptable fit. The RMSEA index approximates how well the model would fit the population covariation matrix based on unforeseen, but feasible, parameter values. The models being tested in this study would be deemed a good fit if three out of four goodness of fit criteria were met. Finally, descriptive statistics and zero-order correlations for the observed variables were calculated, along with a description of the model parameters.

Reliability

Inter-item correlations were calculated for the QALGS. This procedure is typically conducted to support the internal-consistency reliability of an instrument using Likert-type scaling. This procedure consists of assigning scores to items in the instrument. Subjects being administered the instrument choose among strongly agree, agree, undecided, disagree, and strongly disagree as responses to a particular item. Each of these responses are then assigned respective numbers (e.g. 5, 4, 3, 2, 1 for positively worded items; 1, 2, 3, 4, 5 for negatively worded items). The Cronbach alpha reliability statistic is then calculated to determine the strength of the correlation between the particular items in question (Isaac & Michael, 1995). This study calculated Cronbach alpha's for 32 items loaded on four constructs: enjoyment, confidence, usefulness and learning preferences (Yingkang & Yoong, 2007), as well as for all the enjoyment and confidence items, usefulness and learning preferences items, and the enjoyment, confidence and usefulness items. In addition, reliability statistics were calculated for all 32 items, subsuming all four constructs. Responses to items 1-32 were coded and entered into a structural equation modeling (SEM) program designed to test measurement model factor structures. All item responses for all subjects were analyzed.

Confirmatory Factor Analysis for the QALGS

CFA tested the statistical hypothesis that the factor structure of the QASG would be maintained in the revised QALGS. A total of five, two-factor attitude models were tested using CFA procedures. The researchers found it impracticable to test these models through any interconnected means, primarily because of redundancy in sub-item wording across the instrument in its entirety. Four two-factor attitude models indicated three observed variables on the confidence factor and two observed variables on the enjoyment factor. One two-factor attitude model indicated five observed variables on the usefulness factor and seven observed variables on the learning preferences factor. Each model contained one ad-

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ditional observed variable that was a precursor for the remaining variables. This variable was not structurally part of the model, but instead served to inform the contextualization of the remaining observed variables for that particular set. All the models were tested using AMOS software, a SEM program. SPSS was utilized in calculating relevant descriptive statistics of the observed variables for each model. The data presented for each model includes the following: Univariate and multivariate descriptive statistics of the observed variables; Zero-order correlations among the observed variables; Chi-square statistics and fit indices for overall fit of the model; A description of the standardized factor loadings and factor correlations for the model parameters; and reliability statistics.

Results of Research

First Measurement Model

The first two-factor attitude model indicated item mean values between 3.27 and 4.16 and standard deviations between 0.75 and 1.11 for the five observed (endogenous) variables (see Table 1). The overall mean for the five items was 3.80, with 0.81 for item variances.

Table 1. Descriptive statistics for the first two-factor attitude model: Reading information from a line graph in science (*N* = 94).

Item	M	SD
C1	4.13	0.81
E2	3.43	1.11
C3	4.16	0.78
E4	3.27	0.99
C5	4.04	0.75

Correlations for the observed variables in the model ranged from low, 0.27 for items C1 and E4, to moderate, 0.71 for items C3 and C5 (see Table 2).

Table 2. Correlations for the first two-factor attitude model: Reading information from a line graph in science.

Item	C1	E2	C3	E4	C5
C1		0.53	0.60	0.27	0.51
E2			0.55	0.64	0.43
C3				0.32	0.31
E4					
C5					

The first two-factor attitude model fit well with the data statistically (χ^2 [4, N = 94] = 6.36, p = 0.17), as well as descriptively (GFI = 0.97, CFI = 0.99, RMSEA = 0.08). This model had a moderate inter-factor correlation of 0.60, with standardized correlation coefficients ranging from 0.68 to 0.90 for the confidence factor, and 0.62 to 1.04 for the enjoyment factor (see Figure 6). A Cronbach alpha value of 0.82 was found for the five items analyzed.

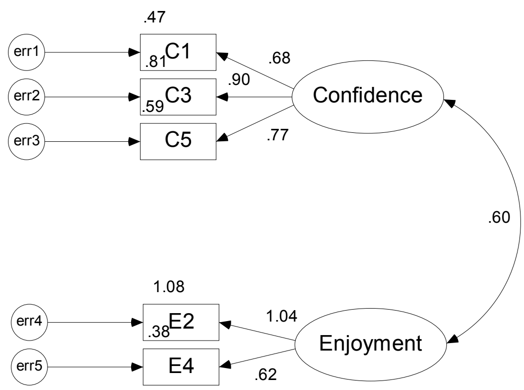

Figure 6: Standardized factor loadings and correlations for model 1.

Second Measurement Model

The second two-factor attitude model indicated item mean values between 2.98 and 4.02 and standard deviations between 0.82 and 0.99 for the five observed (endogenous) variables (see Table 3). The overall mean for the five items was 3.44, with 0.83 for item variances.

Table 3. Descriptive statistics for the second two-factor attitude model: Giving opinions about an issue based on the data shown in a line graph in science (*N* = 94).

Item	M	SD
E6	2.98	0.99
C7	3.39	0.88
C8	3.61	0.91
C9	4.02	0.82
E10	3.18	0.95

Correlations for the observed variables in the model ranged from low, 0.24 for items C7 and E6, to moderate, 0.73 for items E6 and E10 (see Table 4).

Table 4. Correlations for the second two-factor attitude model: Giving opinions about an issue based on the data shown in a line graph in science (*N* = 94).

Item	E6	C7	C8	C9	E10
E6		0.24	0.41	0.40	0.73
C7			0.56	0.51	0.31
C8				0.61	0.48
C9					0.41
E10					

The second two-factor attitude model fit well with the data statistically (χ^2 [4, N = 94] = 2.60, p = 0.63), as well as descriptively (GFI = 0.99, CFI = 1.00, RMSEA = 0.00). This model had a moderate inter-factor correlation of 0.60, with standardized correlation coefficients ranging from 0.66 to 0.84 for the confidence factor, and 0.80 to 0.92 for the enjoyment factor (see Figure 7). A Cronbach alpha value of 0.81 was found for the five items analyzed.

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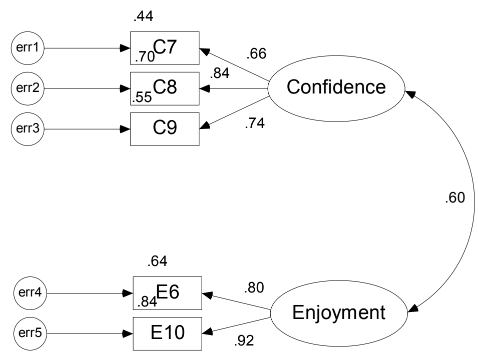

Figure 7: Standardized factor loadings and correlations for model 2.

Third Measurement Model

The third two-factor attitude model indicated item mean values between 2.85 and 3.82 and standard deviations between 0.90 and 0.98 for the five observed (endogenous) variables (see Table 5). The overall mean for the five items was 3.41, with 0.90 for item variances.

Table 5. Descriptive statistics for the third two-factor attitude model: Judging whether a line graph in science is correctly constructed or not (*N* = 94).

Item	M	SD
E11	2.85	0.97
C12	3.73	0.92
C13	3.65	0.90
E14	2.98	0.97
C15	3.82	0.98

Correlations for the observed variables in the model ranged from low, 0.03 for items E14 and C15, to moderate, 0.69 for items E11 and E14 (see Table 6).

Table 6. Correlations for the third two-factor attitude model: Judging whether a line graph in science is correctly constructed or not.

Item	E11	C12	C13	E14	C15
E11		0.33	0.28	0.69	0.19
C12			0.59	0.26	0.55
C13				0.09	0.60
E14					0.03
C15					

The third two-factor attitude model fit well with the data statistically (χ^2 [4, N = 94] = 7.24, p = 0.12), as well as descriptively (GFI = 0.97, CFI = 0.98) The RMSEA index of 0.09 indicated a poor fit. This model had a low inter-factor correlation of 0.29, with standardized correlation coefficients ranging from 0.73 to 0.80 for the confidence factor, and 0.56 to 1.23 for the enjoyment factor (see Figure 8). A Cronbach alpha value of 0.74 was found for five items analyzed.

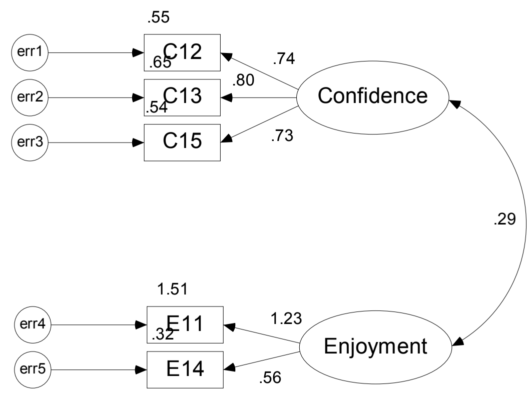

Figure 8: Standardized factor loadings and correlations for model 3.

Fourth Measurement Model

The fourth two-factor attitude model indicated item mean values between 3.14 and 3.81 and standard deviations between 0.79 and 1.05 for the five observed (endogenous) variables (see Table 7). The overall mean for the five items was 3.45, with 0.89 for item variances.

Table 7. Descriptive statistics for the fourth two-factor attitude model: Constructing a line graph in science by hand (*N* = 94).

Item	M	SD
E16	3.14	1.05
C17	3.81	0.90
C18	3.54	0.92
E19	3.17	1.03
C20	3.61	0.79

Correlations for the observed variables in the model ranged from low, 0.15 for items C19 and E20 as well as C17 and C19, to moderate, 0.49 for items C18 and C20 (see Table 8).

Table 8. Correlations for the fourth two-factor attitude model: Constructing a line graph in science by hand.

Item	E16	C17	C18	E19	C20
E16		0.42	0.20	0.43	0.45
C17			0.36	0.15	0.45
C18				0.21	0.49
E19					0.15
C20					

The fourth two-factor attitude model fit well with the data statistically (χ^2 [4, N = 94] = 8.99, p = 0.06), as well as descriptively (GFI = 0.97, CFI = 0.95) The RMSEA index of 0.12 indicated a poor fit. This model had a moderate inter-factor correlation of 0.54, with standardized correlation coefficients ranging from 0.56 to 0.80 for the confidence factor, and 0.42 to 1.03 for the enjoyment factor (see Figure 9). A Cronbach alpha value of 0.70 was found for the five items analyzed.

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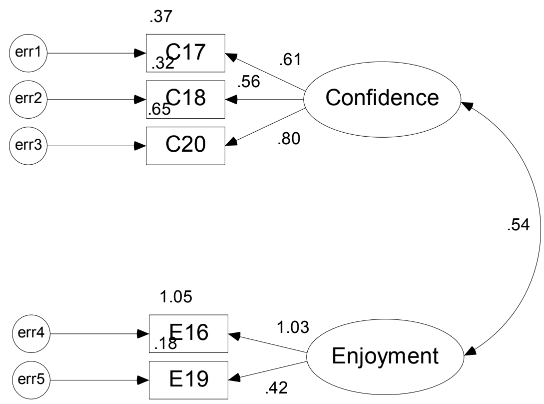

Figure 9: Standardized factor loadings and correlations for Model 4.

Fifth Measurement Model

The fifth two-factor attitude model indicated item mean values between 2.55 and 4.38 and standard deviations between 0.57 and 1.05 for the 12 observed (endogenous) variables (see Table 9). The overall mean for the 12 items was 3.95, with 0.68 for item variance.

Table 9. Descriptive statistics for the fifth two-factor attitude model: Extent of agreement with each statement (*N* = 94).

	U21	LP22	LP23	U24	LP25	U26	LP27	U28	LP29	LP30	U31	LP32
M	4.38	4.02	4.31	3.98	3.39	4.33	4.10	4.11	4.04	4.06	4.06	2.55
SD	0.57	0.89	0.75	0.90	1.03	0.68	0.73	0.86	0.89	0.77	0.62	1.05

Correlations for the observed variables in the model ranged from low, 0.03 for items U24 and LP29, to moderate, 0.62 for items U21 and U26 (see Table 10).

Table 10. Correlations for the fifth two-factor attitude model: Extent of agreement with each Statement.

Item	LP22	LP23	U24	LP25	U26	LP27	U28	LP29	LP30	U31	LP32
U21	0.32	0.45	0.31	0.14	0.62	0.35	0.44	0.33	0.38	0.54	0.32
LP22		0.44	0.17	0.09	0.27	0.15	0.44	0.27	0.37	0.47	0.27
LP23			0.26	0.22	0.35	0.24	0.43	0.48	0.60	0.38	0.12
U24				0.04	0.17	0.31	0.33	0.03	0.31	0.43	0.20
LP25					0.20	0.16	0.36	0.26	0.28	0.11	0.04
U26						0.26	0.04	0.15	0.23	0.44	0.40
LP27							0.42	0.04	0.27	0.39	0.11
U28							0.48	0.36	0.35	0.57	0.25
LP29									0.39	0.27	0.16
LP30										0.40	0.14
U31											0.34

The fifth two-factor attitude model did not fit well with the data statistically (χ^2 [53, N = 94] = 100.34, p = 0.000). Descriptively, the data fit well with two indices (GFI = 0.86, CFI = 0.85). The RMSEA index of 0.10 indicated a poor fit. This model had a moderate inter-factor correlation of 0.78, with standardized correlation coefficients ranging from 0.46 to 0.76 for the usefulness factor, and 0.30 to 0.76 for the learning preferences factor (see Figure 10). A Cronbach alpha value of 0.81 was found for the 12 items analyzed. Overall, the model did not fit the data well using CFA, however, it did achieve a moderate-high reliability statistic.

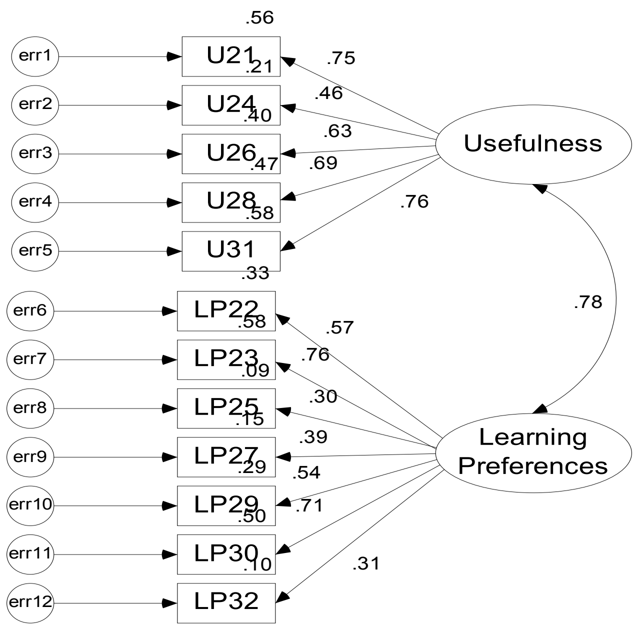

Figure 10: Standardized factor loadings and correlations for model 5.

Reliability Statistics

Reliability statistics for each of the constructs indicated that overall reliability of the 32 items in the revised QALGS was 0.90, while the construct with the lowest reliability was learning preferences, 0.67 (see Table 11). For the constructs enjoyment, confidence, and usefulness a reliability coefficient of 0.91 was found.

Table 11. Reliability statistics for the revised questionnaire of attitude toward line graphs in science (N = 94).

Constructs	Number of Items	α
Enjoyment	8	0.89
Confidence	12	0.86
Usefulness	5	0.77
Learning Preferences	7	0.67
Enjoyment and Confidence	2	0.90
Usefulness and Learning Preferences	12	0.81
Enjoyment, Confidence, and Usefulness	25	0.91
Enjoyment, Confidence, Usefulness, and Learning Preferences	32	0.90

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Discussion

Confirmatory Factor Analysis found that the revised QALGS measure was supported in its psychometric properties against the QAGS. Reliability statistics indicated an overall Cronbach alpha of 0.90 for 32 items. The learning preferences construct had the lowest Cronbach alpha value of 0.67. The first measurement model fit the data well both statistically (χ^2 [4, N = 94] = 6.36, p = 0.17) and descriptively (GFI = 0.97, CFI = 0.99, RMSEA = 0.08). The second measurement model fit the data well both statistically (χ^2 [4, N = 94] = 2.60, p = 0.63) and descriptively (GFI = 0.99, CFI = 1.00, RMSEA = 0.00). The third model fit the data well both statistically (χ^2 [4, N = 94] = 7.24, p = 0.12) and descriptively (GFI = 0.97, CFI = 0.98), with the exception of the RMSEA index (0.09) indicating a poor fit. The fourth model fit the data well both statistically (χ^2 [4, N = 94] = 8.99, p = 0.06) and descriptively (GFI = 0.97, CFI = 0.95), with the exception of the RMSEA index (0.12) indicating a poor fit. The fifth two-factor attitude model did not fit well with the data statistically (χ^2 [53, N = 94] = 100.34, p = 0.000) and fit well descriptively with two indices (GFI = 0.86, CFI = 0.85). The RMSEA index of 0.10 for this model indicated a poor fit. Reliability statistics for models 1-5 were 0.82, 0.81, 0.74, 0.70, and 0.81, respectively.

The psychometric properties of the revised QALGS instrument were closely represented to those of the QASG instrument. Despite the differences found in the fifth measurement model, the researchers dismissed the non-equivalence for two reasons. First, the authors of the original QASG determined that the learning preferences construct was not one-dimensional (Yingkang & Yoong, 2007). The CFA procedure in this study verified that assertion, as the standardized correlation coefficients ranged between 0.46 and 0.76 for learning preferences. However, a reliability statistic of 0.67 provided mediocre, but acceptable support for that construct. In addition, the Cronbach alpha for all 32 items in the QALGS was 0.90, indicating that as a global measure, attitudes toward line graphs in science was adequately measured – even with the embedded presence of learning preferences as a construct. Second, the fifth model had an inter-factor correlation of 0.78, indicating that the learning preferences and usefulness constructs were moderately correlated. The researchers believe that because only the context of the original instrument was modified, along with the removal of 17 items, the revised instrument retained its original properties. Overall, and for the purposes of this study, the assumption is that the QALGS is both a valid and reliable measure of elementary pre-service teachers' attitudes toward line graphing in science.

Conclusion

The psychometric outcomes associated with this study have implications for teacher education programs emphasizing science teaching and learning. In administering the QALGS, uncovered negative attitudes might indicate difficulties in learning and subsequent teaching of line graphs among pre-service teachers. These attitudes could limit the degree to which pre-service teachers develop *graphical tendencies*, and in turn could disrupt the constancy in which line graphing is taught – if at all. In terms of their inquiry-based ventures into best-practice science teaching, such attitudes could drastically diminish the effectiveness of visually communicating data in science. Consequently, or as an approach to prevent such a circumstance, science teacher educators should focus on improving pre-service teachers' attitudes towards line graphs while teaching both process and content oriented science courses. On the other hand, if the QALGS were to be administered upon conclusion of a semester, uncovered positive attitudes might indicate success in having promoted positive dispositional supports. It would be pragmatic for science teacher educators to consider encouraging a positive support system to achieve this. Future research should incorporate the use of the QALGS to investigate attitudes towards line graphs in science both before and after a rigorously prescribed affective intervention, one that would reflect the constructs examined as part of this study.

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