EXAMINING GRADUATE STUDENTS' PRIOR MATHEMATICS/STATISTICS EXPERIENCES AND THEIR STATISTICS SELF-PERCEPTIONS: A THIRD ORDER STRUCTURAL MODEL WITH LATENT VARIABLE ANALYSIS

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The proposed presentation will demonstrate the causal link between prior mathematics/statistics coursework experiences (PME) and Statistics Self-Perception (SSP)*, using structural equation modeling (SEM) techniques. This was accomplished with data from n = 238 graduate students enrolled in their first graduate statistics class. Students were asked to complete inventories: Statistics-Related Self-Efficacy (Finney, 2003), Statistics-Related Attitudes (Schau et al, 1995), and Statistics-Related Anxiety (Cruise, Cash, & Bolton, 1985). SEM was used to demonstrate that these three constructs support a higher order construct of SSP. The resultant model demonstrates a strong link between PME and SSP. Additionally the relationship to participant demographic variables (gender, age, ethnicity, prior college mathematics/statistics classes, etc.) is examined.*

INTRODUCTION

A number of researchers have suggested that a student's prior mathematics and statistics experiences (PME) may be a prime factor influencing the student's performance and mind-set when it comes to learning statistics (e.g., Baloğlu, 2003; Kottke, 2000; Suinn & Winston, 2003). A substantial amount of the research in the area of statistics education has considered some variation of PME as a factor (e.g., Cashin, 1999; Kottke, 2000; Nassar, 2004). Research also suggests that understanding students' PME can help instructors to have some insight into why certain self-perceptions exist (Nassar, 2004; Suinn & Winston, 2003). Therefore, the influence of PME should be considered when investigating students' perceptions regarding their required statistics coursework, and is something that will be examined in the present investigation.

The present investigation begins by first demonstrating the discriminant validity of each primary factor, as well as demonstrating that a significant relationship exists between the primary factors, Statistics-Related Self-Efficacy (SRSE), Statistics-Related Attitudes (SRAt), and Statistics-Related Anxiety (SRAx). Secondly, structural equation modeling was used to confirm the construct validity of the primary factors with the data collected for this study. Next, the present investigation establishes the justification of a higher-order construct, SSP, which efficiently explains the shared variance of three primary factors. This is accomplished through a bi-factor model which eloquently demonstrates the validity of the third-order factor, not seen in the existing research. The reduced model is then used to demonstrate the causal link between PME and SSP as well as the causal link between PME and the primary factors.

METHODOLOGY

Participants

The participants were *n* = 238 graduate level students enrolled in statistics courses offered in the departments of biological science, education, geography, and psychology at a large Mid-Western university. Participants were invited to participate during class time, and were incentivized with $5 for their participation. The response rate was 98.75%.

Instrumentation

The Current Statistics Self-Efficacy (CSSE) inventory is a 14 item instrument developed by Finney and Schraw (2003) to assess the one-dimensional construct of self-efficacy. With this instrument, respondents are asked to rate their current belief in their ability to complete tasks related to statistics using a 1-to-5 response scale. Secondly, the Statistics Anxiety Rating Scale (STARS-1) is an instrument developed from the original STARS inventory by Cruise, Cash, and Bolton (1985). The STARS-1 is comprised of the 23 items of the STARS (Cruise et al., 1985) as a measure of statistics anxiety across three subscales: (1) anxiety related to interpretation; (2)

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statistics class and test anxiety; and (3) anxiety about asking for assistance. Lastly, the Student's Attitudes Towards Statistics (SATS) 28-item inventory is an instrument developed by Schau and colleagues (1995) to assess four components associated with student attitudes toward statistics. According to Schau et al., these components include: (1) feelings about statistics; (2) attitude about intellect for statistics; (3) attitudes about the usefulness and relevance of statistics, and; (4) attitudes about the difficulty of statistics, based on a "strongly agree" to "strongly disagree" five-point scale.

Reliability analyses were conducted using SPSS in order to assess the consistency of participant responses on the scales. A Cronbach's Alpha (Cronbach, 1951) was calculated for the data collected with each instrument in an effort to analyze the internal consistency of items in each scale. These analyses, conducted on the ordinal responses, revealed acceptably high levels of reliability (Thompson, 2003, p. 256) for each instrument, with an $\alpha = 0.917$ on the 14 items of the CSSE inventory, an $\alpha = 0.918$ on the 23 items of the STARS-1 inventory, and an $\alpha = 0.924$ on the 28 items of the SATS inventory. The unidimensional reliability estimates are provided in Table 1.

Table 1. Cronbach's Alpha for Primary Factors

Construct	Sub-Construct	Number of Items	Cronbach's α
Self-Efficacy	One-Dimensional	14	0.917
Attitude	Affect	6	0.889
	Cognitive	6	0.822
	Value	9	0.820
	Difficulty	7	0.639
Anxiety	Interpretation	11	0.842
	Class/Test	8	0.889
	Assistance	4	0.776

Data Procedures

Once data were collected, a number of procedures were used to prepare the data for subsequent analyses. First, data were examined for missing values. A total of sixteen item-responses were incomplete. Since there was no pattern to the missing responses, multiple imputation procedures, generated through the Linear Structural Relations program (LISREL® 8.8, 2006), were used to complete the sixteen missing responses. In addition to the inventory items, participants were asked to complete a number of questions regarding their demographic information, academic careers, including a number of questions about prior mathematics classes. Full details of these questions can be provided. Lastly, a SEM procedure outline by Larwin & Harvey (2012) was used to systematically reduce the number of items in the three inventories from 65 items to 40 items.

RESULTS

Final Model Results

Due to page limitations, only final model results are presented in this writing. The single-factor model of PME was developed for inclusion in a causal model linking this single-factor to the reduced 40-Item model of SSP. This factor included three items specifically aimed to understand what the students' felt about their prior experience with both mathematics and statistics experiences. These items have been used as indicators of PME in prior research, however most researchers have generated their factors through non-SEM analyses (e.g., Bradsma, 2000; Cashin, 1999; Luh, Guo, & Wisenbaker, 2004). A causal model was assessed to see if PME is a predictor of SSP and the primary factors of SRSE, SRAt, and SRAx, as hypothesized.

Causal Model of PME on the Primary Factors

It is hypothesized that PME as a direct predictor of each of the second-order factors (Self-efficacy, Attitude, and Anxiety). The standardized loadings of the effect of PME on the primary factors is reported in the full causal model are presented in Figure 1.

$$\Gamma = \left[\begin{array}{c|c} \eta & \mathrm{Pr}\,ior Math / Stats Experiences \\ Efficacy & 0.757\ (0.074) \\ Attitude & 0.952\ (0.363) \\ Anxiety & 0.852\ (0.132) \end{array}\right]$$

Figure 1. Effect of PME on the primary factors

All the γ-coefficients are positive and significant at the α = 0.05 level. Comparatively, the effect of PME is strongest on SRAt and weakest on SRSE ($SB\chi$=3204.50, p<.001, CFI = 0.963, NNFI= 0.961, RMSEA = 0.0617). In the model in which PME factor was introduced as a predictor of the primary factors revealed that PME accounted for 57.3% of the variance in SRSE, 90.6% of the variance in SRAt, and 72.9% of the variance in SRAx. In summary, this model fits the data and the effects of PME on all the primary factors are significant.

Causal Model of Prior Mathematics/Statistics Experience On Statistics Self-Perception

Similar to the research of Dolan et al. (2006), a secondary model in which PME predicts the third-order construct, SSP, was also developed. The initial model, in which PME directly predicted the primary factors, was compared to the secondary model in which PME predicted SSP for assessment of measurement invariance. The standardized loadings of the third-order factor, SSP, on the PME, in the second causal model are presented in Figure 2.

$$\Gamma = \left[\begin{array}{c|c} \eta & \mathrm{Pr}\,ior Math / Stats Experiences \\ Statistics\ Self-Perception & 0.461\,(0.102) \end{array}\right]$$

Figure 2. Effect of PME on SSP

All factor loadings and reliabilities (R^2) values were significant (SB_χ=3102.50, p<.001, CFI = 0.966, NNFI= 0.964, RMSEA = 0.0594). When introduced as a predictor of the third-order factor, SSP, PME was found to account for 21.2% of the variance in SSP.

Finally, analysis sought to use latent variable scores extracted from the resultant causal model in an effort to address the effect of a number of exogenous demographic variables on the latent constructs explored in the investigation. Prior mathematics coursework, expected grade, and discipline area were found to be significant moderators. Gender, age, ethnicity, GPA, degree level (Master's vs. doctorate) and course hours completed were not found to be significant.

CONCLUSION

The current investigation demonstrates a full structural model linking PME to the 40-Item Factor Model of SSP. As these analyses suggest, PME is a significant predictor of each of the primary factors (SRSE, SRAt, and SRAx). Additionally, PME was found to be a significant predictor of the third-order factor, SSP. Although these two models were found to be measurement invariant, as expected, the amount of variance explained in the primary factors by PME for the primary factors was substantially higher relative to the amount of variance explained in the third-order factor, SSP, by PME. These results suggest that understanding the linkage between student's perceptions and PME should be taken into consideration in the development and structuring of required graduate statistics courses so that learning is sustained beyond the students' academic career. Additional details/recommendations will be provided at the proposed presentation.

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