Structural Equation Modelling: Tips for Getting Started with Your Research

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At a time when numerical expression of data is becoming more important in the business of obtaining grant money research tools such as structural equation modelling (SEM) are becoming more popular. Structural equation modelling enables researchers to show relationships between variables numerically. It is of particular use to educational researchers who are interested in developing or using standard questionnaires in their research. This session will introduce SEM and explore its uses in educational research to enable the reader to decide whether it is a tool to use to add an extra dimension to their research findings.

Introduction

"Structural equation modelling (SEM) uses a variety of models to show the relationships between observed variables with the same basic goal of providing a quantitative test of a theoretical model hypothesised by a researcher." (Schumaker & Lomax, 2010, p. 2). The models developed using SEM can be tested to show how sets of variables define concepts and how they are related. As an example, an educational researcher might hypothesise that a student's home environment would affect their later academic achievement (Schumaker & Lomax, 2010). In this example the researcher believes, based on theory and observed research, that sets of variables related to the impact of an environment external to the school (the home) on learning are linked to academic achievement. The goal of SEM is to determine the extent to which the model is supported by the data that is gathered during research (Schumacker & Lomax, 2010).

Historically SEM developed from related models: regression, path, confirmatory factor and SEM (Schumaker & Lomax, 2010). Specifically, SEM was developed from a combination of path and factor analysis. Path analysis models allow a study of the structural relationships between observed models. In contrast, factorial models measures the relationships between survey item responses and underlying theoretical constructs that are not directly modelled (Cunningham, 2008). In 1973 Karl Jöreskog combined the factorial analytic work of Spearman and Thurstone with the path analysis work of Wright to develop the generalised linear model which is now known as SEM. Jöreskog subsequently developed the first computer package LISREL which led to SEM becoming more available to a range of discipline areas including business, education and the social sciences (Cunningham, 2008). The aim of this paper is to discuss the development and use of SEM in educational research in order to assist the reader in deciding whether to adopt it as a methodology.

Deciding whether to use structural equation modelling

When deciding whether to use SEM in research it is important to consider the following four points as a rationale for adopting it as a methodology: Researchers are becoming more aware of the need to use multiple measured variables to better understand their research area. Basic statistical models are only useful for analysing a limited number of variables and are not appropriate for developing sophisticated theories. In contrast, SEM is capable of statistically modelling and testing complex phenomena and is therefore becoming the preferred method for confirming (or not) theoretical models, quantitatively (Schumaker and Lomax, 2010).

In addition, greater recognition is given to the validity and reliability of "observed scores from measurement instruments" (Schumaker and Lomax, 2010, p. 7). There is a concern that measurement error from statistical analysis is not being adequately accounted for in the literature (Schumaker and Lomax, 2010). Structural equation modelling avoids this issue as it accounts for measurement error when data analysis is conducted (Schumaker and Lomax, 2010).

The maturation of SEM over the last 30 years now allows for analysis of more advanced models. Multi-level modelling is now possible. For example, educators or policy makers interested in regional, school-level, teacher and student data can now model the inter-relationships between these varaibles through multi-level modelling (Schumaker and Lomax, 2010).

Finally, SEM software programs have changed significantly from the early versions in which researchers used matrix and Greek notation to input program syntax. Now, more user-friendly windows-based programs with pull-down menus and drawing programs which input syntax are available (Schumaker and Lomax, 2010).

Understanding the construction of structural equation models

Structural equation models are either measurement models or structural models. Measurement models describe the relationships between observed variables (measured through the survey or questionnaire) and the concepts that those variables are hypothesised to measure (Weston & Gore, 2006). Structural models define the relationships between variables.

Figure one is a measurement model. Measurement models include latent variables, represented in the figure by ellipses, which are factors or concepts that are hypothetical and are not measured. The rectangles represent measured variables. These variables are measured by survey responses. Single direction arrows indicate a correlation between the latent variables and the measured variables. Finally the paths are represented by bidirectional arrows.
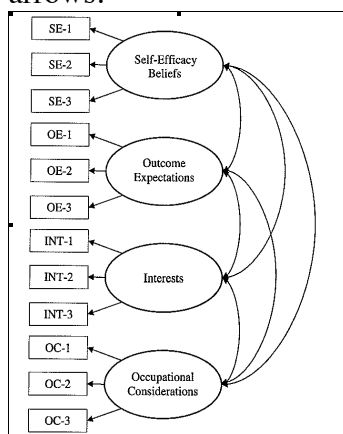

Figure 1: A measurement model (from Weston & Gore, 2006, p. 725)

Structural models specify hypothesised relationships among latent variables. In this example (figure 2) Weston and Gore (2006) hypothesise that a person's self-efficacy beliefs and outcome expectations (right hand side of the model) are mediated by their interests which, in turn, affects their occupational considerations (left hand side of the model).
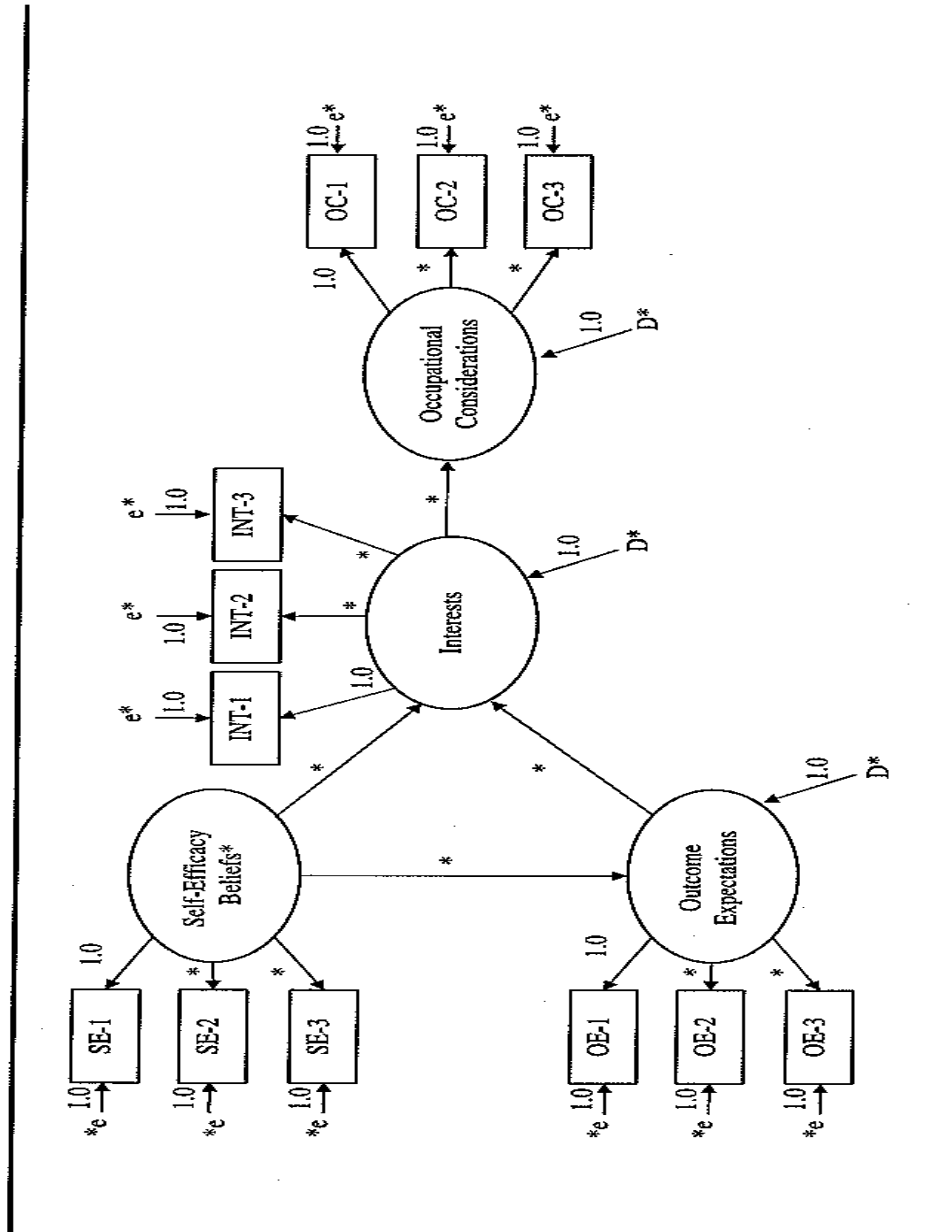

Figure 2: A structural model (from Weston & Gore, 2006, p. 727)

Important Considerations when using Structural Equation Models

Once a decision has been made to use SEM as a research method the reader needs to decide whether they will adopt surveys that have already been developed and have been identified in the literature as being valid and reliable. Or the reader may wish to develop their own. The reader needs to be aware that if they use of series of different

previously developed surveys in their research that there may not be a strong relationship between them. This will affect the robustness of the model and, consequently, the results.

Another very important consideration is the intended sample size. Most authors recommend a sample size of at least 100 to generate good results *(Cunningham, 2008; Schumaker & Lomax, 2010; Weston & Gore, 2006; Worthington &Whittaker, 2006)*. A sample size smaller than 100 will not be reliable and consequently SEM should not be used.

An Example from Educational Research

A 2009 article by Ravens-Sieberer and her colleagues examined the relationship between health and school experience. This study was conducted in 35 countries and regions of Europe, North America and Israel under the auspices of the World Health Organisation (WHO) and had 162, 306 participants in three age groups (11, 13 & 15 years). The study used a WHO developed "Health behaviour in school-aged children survey" which had previously been developed.

The study hypothesised that there was a relationship between the following factors:

- Social support (classmates);

- School demands;

- Satisfaction with school;

- Academic achievement;

- Life satisfaction;

- Emotional health

The survey asked the students to respond to items through a variety of Likert scales. Each factor had the following item structure: Social climate (three items), demands (one item), school adjustment (two items) and health (one general question and eight items on psychosomatic symptoms). Life satisfaction was measured by the Cantrill ladder where the top of the ladder represented the best possible life (10) and the bottom the worst possible life (0) (Ravens-Sieberer et al., 2009). A cautionary note needs to be raised here - most authors in the area of SEM recommend that each factor has at least three items. The lowest possible number is two, and even then the items must have a correlation of 0.8 or above (Cunningham, 2008; Schumaker & Lomax, 2010; Weston & Gore, 2006; Worthington &Whittaker, 2006). This should been considered when interpreting the results of this study.

Figure three below presents the results of the survey. It is evident that there is an overall stronger correlation with latent variables on the right hand side of the model in comparison with the left hand side. The correlation between the latent variables social climate and demands are not reported in the model, but are low (r = 0.21).
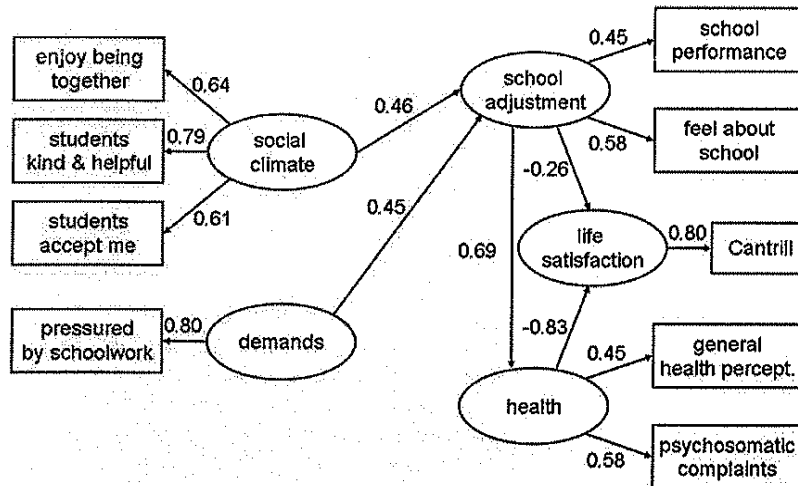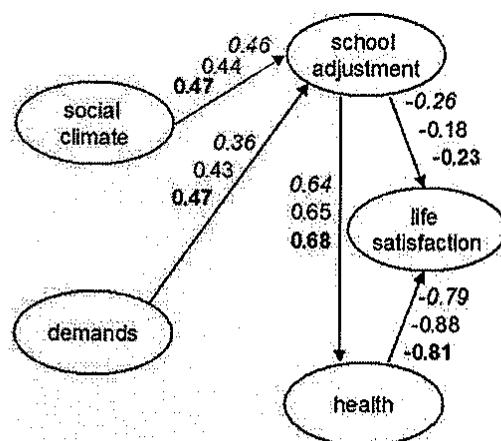
Figure 3: Structural equation model for results of survey (from Ravens-Sieberer et al., 2009)

Based on these results the researchers could have improved the correlations between latent variables by having more items in the survey, which may have improved the relationships between the latent variables on the left hand side of the model.

There were less marked differences between the age groups than the researchers hypothesised. With the model fitting the 11 year old group better than any other age group. Figure four shows the differences in the correlations between the age groups. Ravens-Sieberer et al., (2009) concluded that according to their findings, school was an important factor in determining student health and that social climate and school demands were equally important for girls. In contrast, for boys social climate was more important. The finding that the model fitted the 11 year old data did not support the researcher's hypothesis that school demands would have a more marked effect (and stronger correlation) for older students than their younger counterparts.

Note: Standardized coefficient of Lisrel analysis for 11-year olds (bold), 13-year olds (normal) and 15-year olds (italic) separately
Source: Samdal and Dür (2000)

Figure 4: A comparison of correlation coefficients between latent variables between 11, 13 and 15 year old participants (from Ravens-Sieberer et al., 2009).

The results from this study demonstrate the importance of having sufficient numbers of items in each factor that support the development of a strong model. It is hoped that the illustration of this study will give the reader some indication of how SEM can be used in educational research.

Some ideas for moving forward with structural equation modelling

If the reader is interested in using SEM in their research it is recommended that an introductory SEM course is completed. The Australian Consortium for Social and Political Research Incorporated (ACSPRI) (http://www.acspri.org.au/courses) runs regular courses at universities on the eastern Australian seaboard. In addition to this the articles and book listed in the reference list are a good place to start.

Conclusion

This paper discussed the historical development of SEM and considered a rationale and important considerations for its use as a research methodology. Structural equation modelling was then illustrated using an example from educational research. The reader is encouraged to undertake a SEM course and read widely in the area before adopting SEM as methodology.

References

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