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Science achievement determinants: factorial structure of family variables

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In this article I report on how family variables can be included in an analysis of the determinants of science outcomes (science achievement and attitude). The family latent factor is regarded as an essential determinant of science outcomes. The problem arises in connection with what constitutes the family factor and which variables to use in its measurement. The problem is particularly prevalent when structural equation modelling is used to analyse the determinants of science outcomes. Three aspects to this problem are presented in this article. Firstly, the identification of variables used in the literature for measuring the family latent factor. Secondly, the use of confirmatory factor analysis to test the factorial structure of the family latent factor. Thirdly, the use of the factorial structure in structural equation models of science achievement and attitude. The emphasis is on the first two aspects. The third aspect is reported elsewhere.

The research problem

The family plays an important role in determining the academic achievement (Castejon & Vera-Munoz, 1996:22) and attitudes (Simpson & Oliver, 1990:6) of children. Researchers have identified family variables that could possibly explain how the family influences certain aspects of the child's functioning. These family variables include family structure, parents' occupation and education, parental socio-economic status, parenting styles, parental beliefs, parental involvement and support in school-related matters and the perceptions children themselves have about such involvement and support. Most researchers only ascribe a few of these variables to familial influence in their studies. Also, since most studies do not use the same set of family variables, their findings often do not yield consistent results.

Furthermore, variables used by researchers to measure the family are numerous. It therefore becomes impractical to include most known family variables in a single investigation. The large number of observable variables used to measure aspects of the 'family' gives an indication of the abstract nature of this concept. The family is therefore a latent (abstract) factor that can be measured through the use of a number of observable variables. In order to measure the family latent factor properly, main dimensions need to be included in a measurement scale. In structural equation modelling, factors that do not include most dimensions of the latent factor causes problems in the estimation of the theoretical model. This article therefore focuses on determining which dimensions best represents the family latent factor, that is, the factorial structure of the family latent factor.

Literature review

Researchers (Tamir, 1989:30; Welch, Anderson & Harris, 1982:50) have shown that the effect of the family on achievement is dependent on specific subjects. Areas such as reading are more related to the family environment whereas others such as science are more affected by schooling. In this regard, Tamir (1989:33) reports that not a single family variable (parents' country of birth, parents' occupation, parents' education, family size, number of books at home) accounts for more than 5% of the variance in science achievement. A limitation of Tamir's study, however, is that it failed to include other equally important aspects of the family environment such as parenting styles, family interactions, perceptions children have concerning family support, and the like. Omission of other dimensions in variables that constitute a latent factor is common in the literature and results in inconsistent results pertaining to the latent factor under consideration. This article attempts to address this issue in connection with the family latent factor.

In other studies, however, Tamir found that home background exerts a significant but small influence on science achievement (1987: 92) and that a science-oriented home background affects positively functional knowledge and understanding in science courses (1991:27). Ma and Kishor (1997:99) found a statistically significant relationship between perception of family support and achievement in mathematics. Perception of family support was defined as students' perceptions of parental attitudes and behaviours towards mathematics, including parents' assistance, expectation, and encouragement in their children's mathematics learning. Similarly, Simpson and Oliver (1990:6) found that family support of science and attitude toward science of same sex parent accounted for thirty nine percent of the total variance in students' attitudes toward science. Simpson and Troots (1982:765) found that family commitment correlated strongly with students' science affective measures.

Parental socioeconomic status

Parental socioeconomic status, as an aspect of the child's family background, has repeatedly been shown to influence scholastic achievement (Mau, 1997:272; Castejon & Vera-Munoz, 1996:22; de Jong, 1993:203; Anderson, 1987:52; Gordon, 1986:72-73). Hobbs (cited in Caldwell & Ginther, 1996:141) asserts that socioeconomic status is the single best predictor of academic achievement, with low socio-economic status predicting low achievement. According to Brantlinger

(1990:305), low-income students, compared to more affluent peers, have less positive school experiences and outcomes including intelligence and achievement test scores, grade point averages, class rank, and educational attainment. Also, students from a low socioeconomic background constitute the largest population of individuals considered to be at-risk of not graduating from high school (Caldwell & Ginther, 1996:141).

A similar pattern is found in the relationship between parental socioeconomic status and science achievement. From a synthesis of 13 studies, Kremer and Walberg (1981:17-18) reported a positive relationship between parental socioeconomic status and science learning. Specifically, students from higher socioeconomic status homes scored higher on achievement measures of logical operations, science attitudes and interests, general cognitive learning in science, critical thinking and factual learning. In a meta-analysis carried out by Fleming and Malone (1983:486), socioeconomic status was found to have a positive but low correlation ($r = 0.25$) with measures of science achievement. Crane (1996:309) also reported a low correlation between socioeconomic status and achievement in mathematics (a science related subject). The low correlation further decreased substantially when variables such as home environment were controlled.

Other researchers, however, argue that it is actually what goes on in the family (that is, the family climate) that predicts students' achievement and not the child's socioeconomic status *per se* (Ma & Kishor, 1997:92; de Jong, 1993:203-4). Variables like parenting styles, parental support and encouragement for their child's schooling, intellectual stimulation, et c., play a major role in the achievement of all pupils, including low socioeconomic status students.

Parenting styles

Another family variable that is an important factor in the achievement of science students is parenting style. Hein and Lewko (1994:274) reported that there is a positive relationship between authoritative parenting and academic achievement in science. Authoritative parenting is "characterised by parental responsiveness, encouragement, and open communication in addition to the establishment and firm enforcement of rules and standards" (1994:263). These authors found that family-related measures that were specifically related to science and mathematics achievement were parental encouragement to pursue a career in the sciences, parental encouragement to excel in science and mathematics, "science sexism" in parental views, and perceived parental expertise in science and mathematics. Family structures, family values, and the cultural and physical settings of family life are therefore important determinants of science achievement (Lees, 1994: 70).

Parental beliefs

According to Jacobs (1991:518) there is a growing body of literature establishing the importance of parents' beliefs in influencing their children's achievement attitudes and academic performance. Jacobs referenced studies that demonstrated that parents' beliefs and expectations are related to the child's self-perception of ability and achievement expectations. These studies further pointed out that parents' beliefs about children's abilities have an even greater influence on children's achievement attitudes than does previous performance. Similarly, Mau (1997:267) cites a number of studies that suggested that cultural upbringing is a strong factor contributing to the educational success of Asian students. According to Mau, Asian culture believes that a deficiency can be overcome with diligence. As such the value of hard work is prevalent in Asian families. Mau's study also demonstrated that Asian students spend a lot of time on homework and academic related activities. Finally, Asian students perceived significantly higher parental educational expectations.

Method

The research group

The research group consisted of secondary school students doing physical science in Stds 7 and 8. Five hundred and forty-eight students (419 in Grade 9, 126 in Grade 10, 282 girls, 262 boys, 3 missing observations) were included in the investigation by making use of a single-stage simple random sampling of clusters (Pedhazur & Schmelkin, 1991:334-336).

Operational variables of the family latent factor

The literature review suggests three aspects of the family are particularly related to children's science achievement and attitude, namely, parental socioeconomic status, parental involvement with the child and parental attitudes toward science. The family environment latent factor was therefore measured by formulating items relating to these concepts. All items (except those measuring socioeconomic status) were four-point Likert-type items, ranging from strongly agree to strongly disagree. Validity was established through review of the questionnaire by subject specialists. A small pilot group — pupils and teachers — was utilized to assess item difficulty and issues such as language. The variables used to measure these concepts are described below.

Socioeconomic background (SES)

A brief Socioeconomic Background Scale requiring the subjects to give information on their parents' educational (PEDU) and occupational (POCC) background as well as on some economic facilities available at home (PFAC) was constructed. This scale was preferred for its relative ease of administration and interpretation compared to those requiring, say, involvement of parents and other complex indices. Measurement of SES is complex and detailed discussion of this aspect is beyond the scope of this article.

Parental involvement (PI)

Parental involvement measures whether parents help and participate in children's schooling. It also measures the atmosphere in the family, i.e. whether parents are authoritative or *laissez faire*. Authoritative parental styles were shown in the literature review as creating a conducive atmosphere in the family for academic self actualisation. A scale was found in the literature which measured these aspects of parental involvement, namely helping, controlling, supporting, and participating (Mau, 1997). The scale contained 15 items whose scores ranged from 15 to 60. Examples of adapted items in each of these four categories were:

Helping (PHELP):	"*My parents/guardians help me with my homework.*"
Controlling (PCONTROL):	"*My parents/guardians limit my privileges when I get poor symbols.*"
Supporting (PSUPPORT):	"*I discuss my plans and preparation for tests with my parent(s) or guardian(s).*"
Participating (PPARTAKE):	"*My parent(s) or guardian(s) attend school events in which I participate.*"

Parental attitudes (PA)

Parental attitudes toward science measures perceived parental encouragement (PENC) and expectation (PEXP) for the child to do well in physical science, parental encouragement to pursue a science career (PCAREER) and parental competence in physical science (PCOMPETE). The attitudes of the father and mother were measured separately, for example, "*my father/stepfather knows a lot about science*". The highest score of either the mother or father was used as a measure of parental attitudes. The scores were then summed to get a composite score (Hein & Lewko, 1994), ranging from 4 to 16.

Statistical techniques

Factor analysis

The primary goal of factor analysis is to explain the covariances or correlations between many observed variables by means of relatively few underlying latent variables. It can therefore be classified as a data reduction technique. Factor analysis can be approached in two ways, an exploratory or a confirmatory approach. Exploratory factor analysis (EFA) is the more traditional approach. The most distinctive feature of EFA is that a model specifying the relationship between the latent variables and the observed variables is not required. The number of latent variables need not be predetermined, the measurement errors are not allowed to be correlated, and under-identification, which occurs when unique parameter estimates cannot be generated, is common (Bollen, 1989:226-232). In contrast, in confirmatory factor analysis (CFA), a model is constructed in advance, clearly identifying relationships and errors. The number of latent variables is set by the researcher, measurement errors are allowed to be correlated and parameter identification is required.

Several authors (Bollen, 1989:226-232; Pedhazur & Schmelkin, 1991:631; Joreskog & Sorbom, 1989:96) discuss some of the problems of EFA and their limits. The problems discussed by these authors reflect the inability of EFA to accommodate theoretical knowledge. CFA overcomes these shortcomings, but the strengths of CFA can only be exploited once the model is expertly formulated. Once the model is constructed, it can be estimated, and its fit to the data can be assessed. The result is that CFA provides a much more powerful tool in confirmatory research than EFA.

Results

Raw scores were used in the analyses. The reliabilities (coefficient alpha) of parental attitudes, parental involvement and parental socioeconomic status were, respectively, 9.0, 0.80 and 0.60. To use all relevant information in determining the best model, assessment of the fit of the models was based on descriptive, comparative, and substantive criteria. Multiple fit criteria are recommended in the structural equation modelling literature. The following criteria were used: (a) the sign and magnitude of the structural coefficients; (b) small values of chi-square relative to degrees of freedom, i.e. the ratio of chi-square to degrees of freedom; (c) large probability values ($p > 0.05$) associated with model chi-square; and (d) LISREL's fit indices, including the goodness-of-fit index (GFI) and the adjusted goodness-of-fit index (AGFI).

The root-mean-square residual (RMR) is difficult to interpret when unstandardised variables are analysed. It is interpretable when all observable variables are completely standardised in which case small values indicate better fit. The reason small values of chi-square and large probabilities are desirable is that the probability associated with chi-square in the present context can be conceptualized as the probability of obtaining the observed data if the proposed model is true for the population. Because the chi-square statistic is biased upward with large samples, a chi-square ratio between 2 and 3 is often recommended (Reynolds and Walberg,, 1991). The goodness-of-fit indices range from 0 to 1, with higher values indicating better fit. The usual cut-off value for these indices is 0.9.

The second order confirmatory analysis model utilizing all the variables yielded a reasonable good fit ($\chi^2 = 138.76$; df = 41; χ^2/df = 3.38; p = 0.000; GFI = 0.951; AGFI = 0.921; RMR = 0.205). The coefficients of determination for PPARTAKE, PCAREER, PCOMPETE and PFAC, however, were very low (Figure 1). As such, these variables were left out and the model re-estimated. The resultant model fitted the data exceptionally well ($\chi^2 = 6.66$; df = 6; χ^2/df = 1.11; p = 0.353; GFI = 0.996; AGFI = 0.985; RMR = 0.055). The values of the other parameters are given in Figure 2. It can be deduced that the family latent factor has a second order factorial structure.

Discussion

The literature review identified three dimensions of the family latent factor as essential determinants of science outcomes. These three dimensions were used in the construction of a second order structural equation model (Figure 1) which was estimated using data from 548 physical science students. After removing variables with low coefficients of determination, the model was re-estimated. The modified model (Figure 2) fitted the data well. Figure 2, however, shows that the SES factor loaded low and is statistically insignificant. This result was to be expected since the measurement of SES, in the sample used, was particularly difficult. Students were uncertain and guessed about the levels of education of their parents and the occupations they held. A large number of students did not report their family income levels. Omission of SES in structural models could result in under-identification. To circumvent this problem, a first order model can be constructed. In this model, the variables for parental involvement, parental attitudes and SES are aggregated. The resultant family factor will have three observed variables. The estimation of such a model yielded an excellent fit. The chi-square value to degrees of freedom ratio was acceptable (2.91); the probability was greater than 0.05; both the GFI and AGFI were greater than 0.9; all factor loadings had the expected positive sign, were significant ($t > 2$), and relatively large.

Caution must be exercised when estimating a model with three observed variables. When using confirmatory factor analysis with three observed variables, it is necessary to impose an additional con-straint on the model to obtain the degree of freedom required for the chi-square test. Under these circumstances, the best parameter esti-mates are obtained when the constraint that is best supported by the data is imposed. As such, the loading of PA was set to unity. Although this procedure capitalizes on chance to some degree, it was neither required by nor imposed in the subsequent tests of the full models (where other science determinants are included) because of the degrees of freedom afforded by the variables in those models.

It can be deduced from the foregoing that the family latent factor is difficult to measure, particularly in samples where reliable data cannot be obtained with regard to issues like parental income, parental education and occupation. Since parental socioeconomic status is a necessary dimension of the family latent factor — omission of SES increases probability of underidentification — research into mechanisms that can be employed to measure SES reliably is recommended. Finally, this study has indicated that although the family latent factor is usually depicted and used in investigations as a first order construct, that its structure is actually of a second order nature. As such, estimation of structural equation models using the second order family latent factor could be expected to yield better fits.

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Blissymbol learning as a tool for facilitating language and literacy development

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In this study we investigated the learning of Blissymbols by 4 preschoolers with Down's syndrome over a period of 7 months. The results of the study suggest that the children did derive some benefits from the exposure to and the learning of Blissymbols. However, some key issues were identified that need to be considered in the use of Blissymbols for literacy and language learning. These include the number of symbols and time spent teaching these, the word classes of the words taught, the frequency of exposure to each word, children's familiarity with and interest in the themes used in teaching as well as visual complexity of the symbols. Results confirmed the complexity of the process of symbol learning for young children with disabilities.

Introduction

The acquisition of language and literacy skills by young children remains an important issue in facilitating integration and participation in society. The role of graphic symbol systems in the development of these skills is not a new area of research in Augmentative and Alternative Communication (AAC). AAC systems refer to those techniques and strategies used to compensate for the severe expressive communication disabilities of people (Beukelman & Mirenda, 1998: 3). This means that these systems are used primarily to facilitate a person's interactions with those around him/her. Various authors have identified a link between the introduction of AAC systems and language enhancement in children who have little or no speech. Within the domain of AAC intervention, various strategies including gestures, pictures and line drawings such as Blissymbols and Rebus have been used to support the development of language and reading skills.

The benefits of using a visually orientated training approach for children with Down's syndrome have been well described due to their general problems in auditory processing. The use of visually orientated approaches such as the use of gestures or graphic symbols reportedly enhances the development of language, especially expressive language (Launonen, 1996). Much success has been reported by Shepperdson (1994) and Buckley and Bird (1993) in getting these children to read traditional orthography even though initial progress could be slow. It is because of the difficulties inherent in teaching an arbitrary system (such as traditional orthography) to children with mental disabilities that the use of an easier symbol system as a bridge into literacy becomes attractive.

The use of easier graphic systems such as Bliss could provide a meaningful medium through which the child can explore language. Graphic systems refer to symbol systems that include symbols that are spatial and temporal and are conveyed through the visual modality (Musselwhite & St Louis, 1988). Bliss is a semantically based system, which means that it is based on concepts rather than on words and comprises a small number of geometric forms with each element representing a unique meaning. It is easier to learn than traditional orthography (Clark, 1981; Mizuko, 1987; Mirenda & Locke, 1989), yet uses skills such as analysis and synthesis of different elements that underpin traditional orthography. Exposure to print is reinforced by always accompanying the Blissymbol with the written word. Not only can the child achieve success sooner, but the generative characteristics of the system also ensure that the child is exposed to unlimited concepts. The impact which learning a conceptually based symbol system has on the child's mastering of reading and writing skills which requires the acquisition of a letter-based symbol system has, however, not been well researched.

As Blissymbols have traditionally been used for communication with people who have no or very little speech, their application to the area of language expansion and literacy learning has only been addressed peripherally. In view of the importance of literacy learning for children with mental disabilities, however, it is essential that a better understanding be acquired of the process involved in learning conceptually based symbol systems and their possible impact on the child's language learning. Hence it is imperative that more research be undertaken to establish how children acquire Blissymbols and which factors influence this learning process.

The processes used in the decoding and understanding of different kinds of symbol systems have received a fair amount of attention in the AAC literature. Various studies have been done on the differences between symbol sets and systems as regards the ease of learning, iconicity and visual complexity (Hurlbut, Iwata & Green, 1982; Ecklund & Reichle, 1987; Mizuko, 1987). Although these studies have contributed to a better understanding of the processes involved in learning to attach meaning to symbols within an experimental context, few studies have described the processes and factors that could influence the learning of Blissymbols by children with disabilities within a more natural context.

In a previous study, Alant (1994) described the learning of Blissymbols by 4 children with Down's syndrome during an 8-week period. In that study it became clear that, although all the children learned the Blissymbols and were able to retain these symbols ade-