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THE STRUCTURAL EQUATION MODELING AS A COMPONENT OF PhD TRAINING

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The Structural Equation Modeling as a Component of PhD Training

The article discussed the questions of structural equation modeling as a component of applied analysis. The syllabuses of PhD SEM courses of leading universities are analyzed. Course objective: using structural equation modeling methodology to study the problems of social and behavioral science, understanding the strengths and flaws of the method and its limitations, teaching methods of assessment, identification models, test their validity, interpretation, critical evaluation of scientific publications on this subject, using statistical software to perform structural equation modeling analysis, preparation of research reports in accordance with the standards of research and academic publications. The dynamics of popular software of structural equations modeling: AMOS SPSS, Lisrel, Mplus, EQS and popular books of structural equations modeling subject (amazon.com) are discussed. The necessity of including structural equation modeling in the courses for high school of Ukraine for PhD training program in the field of education and social sciences is founded. Key words: structural equation modeling, PhD training program, software structural equation modeling, Lisrel, Amos, R.

The PhD training has recently started in Ukraine. High-quality scientific research is not impossible without the systematic description of the phenomena studied; multidimensionality of the phenomena studied requires the use of multivariate analysis methods that are designed to identify causal relationships, latent factors and so on. A promising direction in the multivariate applied analysis is structural modelling or simulation of structural equation modelling, which is becoming an increasingly popular tool for researchers in education science, psychology and social sciences [1 – 4; 7; 9; 13; 19; 31; 32].

Structural modeling methodology is widely recognized in the West. Studying the basics of structural modeling was part of the professional training of future

researchers who specialize in the social sciences [1; 23 – 29]. In Russia, the idea of structural modeling in relation to psychology is reflected in the works of O. Mitina [3] and A. Naslyedova [4]. Use of SEM with an emphasis on economic research is described by Ukrainian scientist A. Chorny [6]. Unfortunately, in Ukraine the structural modeling means are not applied enough in psychological, pedagogical and social studies in general and in training future researchers in universities, in particular.

The article is aimed at investigating the content of foreign PhD training programs in the field of psycho-pedagogical and social sciences regarding the study of structural equations modelling, the software used in these courses in order to justify the inclusion of these assets in the related PhD training courses in education science and social science in Ukrainian universities.

Structural modeling took shape as the direction of applied analysis in the seventies and eighties of the last century, and developed the ideas of multivariate regression and factor analysis. Its formation is associated with the names P. Bentler, B. Byrne, G. Dunn, J. Ullman.

Structural equation modeling (abbreviated SEM) allows to correlate variables measured during the experiment with hypothetical, latent factors that were established by the researcher at the design stage of the experiment. These methods can provide different types of connection between variables to assess their statistical significance. Intuitively, structural equation represented by specialized path diagrams (Fig.1 – 2).

Thus, the measurement model of the study of the attitude of the user to use the computer shown in Figure 1 has three factors (latent variables): perceived usefulness of computer use, perceived ease of use, and attitude to computer use. Each factor has three indicators, and each indicator – measurement error (e1-e9). In the structural model (Fig. 2) hypothesis is proposed that the attitude of the user to use the computer (ATCU) is a function of the utility (PU) and ease of use (PEU). Usefulness (PU), in turn, is influenced by ease of use (PEW). On the other hand, utility mediates the effect of ease of use in relation to computer use [7].

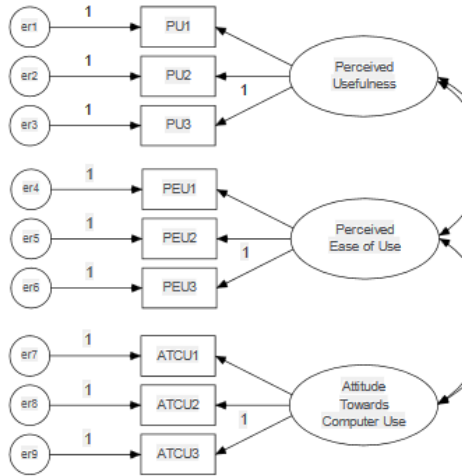


Fig.1.Measurement model

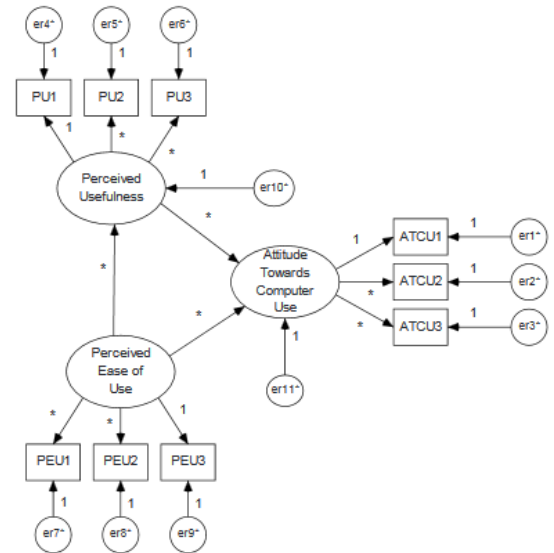


Fig.2.Structure model

The experiment we conducted shows the growing popularity of SEM methodology. The book search for «structural equation modeling» on Amazon.com (on 3/16/2013) gave 59 titles, while in 2016 (1/9/2016) – the number reached 175 books (Fig. 3).



Fig 3.Books for «structural equation modeling» query at Amazon.com

The most popular two books are referenced by 48 other books from the list. The first is the fourth edition of the bestseller “Principles and Practice of Structural Equation Modeling” (Rex B. Kline [13]). Site companion of this publication provides methodological support and offers to download the syntax, data and source files for

all the examples from the book to carry out in the environments Amos SPSS, EQS, LISREL and Mplus. The second is the first edition of “Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach” by Andrew F. Hayes. Online Companion Edition (www.afhayes.com) offers to download macros for SPSS and SAS, which calculates all the examples the book.

Among scientific journals there are those that are entirely devoted to the subject of SEM: “Structural Equation Modeling: an interdisciplinary journal” (<http://www.tandfonline.com/toc/hsem20/current>). “Multivariate Behavior Research”, “Psychological Methods” and “Sociological Methods & Research” also contain the articles related to this topic.

Analysis of the best programs for PhD training in sociology according to Princeton Review's “Gourman Report of Graduate Programs” [18] showed the obligatory presence of the courses in structural equations modelling. In Table 1 we summarized the use of various SEM software in PhD training of the leading universities.

Syllabus courses analysis (tab.1) showed that generally the courses are organized in the form of seminars. Thus the main activity is created at the intersection of lectures, group discussions, software application and interpretation of the results. Educational materials are available through Blackboard or Moodle learning management system. Credits number ranges from 1 to 6: 1-3 credits for introductory courses, and 4-6 credits for advanced courses. Courses are offered for Ph.D training in educational sciences, psychology, sociology, statistics, information systems and business, public health, sports and others. Both proprietary and free software is used for the courses. Most courses consider one main software tool and one additional. But there are courses which require the comprehensive use of several software [14; 27]. Course objective is to use SEM to study the problems of social and behavioral science, to understand the strengths and flaws of the method and its limitations, training evaluation methods, identification models, test their validity, interpretation, critical evaluation of scientific publications on the subject, using statistical software to perform SEM preparation of research reports in accordance with the standards that exist for research and academic publications [22].

Table 1

Links	Software						
	AMOS SPSS	EQS	Mplus	Lisrel	Open Mx	SAS	R Packa- ge
MOOC “Structural Equation Model and its Applications” [12]				+			
Modern social analysis, St. Petersburg [2]			+				
“Structural equation modelling in educational research”, Amsterdam university [27]			+	+	+		
“Latent Structural Equation Modeling”, Vaasa, Finland [14]	+		+	+		+	+
SEM1, Oregon university [20]	+		+				
“Structural equation modelling using LISREL and EQS” (SEM PhD workshop) [26]		+		+			
“Structural Equation Modeling in the IS Discipline”, Mannheim university [24]	+						
“Structural equation models for social and behavioral research”, Iowa State University [28]							
“Structural Equation Models in the Social Sciences”, university Brown [29]				+			
“Causal analysis and structural equation modeling” [10]			+Stata				
“Structural Equations”, University of Leuven, PhD in Statistics [30]				+			
“Structural Equation Modeling”, School of Education University of Pittsburgh [23]			+			+	
“Structural equation modeling: Longitudinal models and multi-group models”, University of Oslo [25]			+				
“Building and Testing Structural Equation Models In the Social Sciences”, University of Michigan [8]	+	+		+			

Here is an example of evaluation of student performance during the course [28]. Homework using statistical software – 8%; critical review of articles on the subject (4 reviews of 4-5 pages) – 30%; statistical analysis (4 reports of 12-15 pages) – 62%. For a critical review the evaluation parameters are provided: for instance, explanation of the basic model evaluated by the author (20% of the grade); discussion of critical errors made by the author (40%); explanation of correct evaluation of casual effect (40%) [28]. Some programs offer exam and final project in the form of independant mini-survey on the use of SEM during the course.

Fig. 4 presents a comparative analysis of popular search query of SEM software: AMOS SPSS, Lisrel, Mplus, EQS from 2004 to 2012.

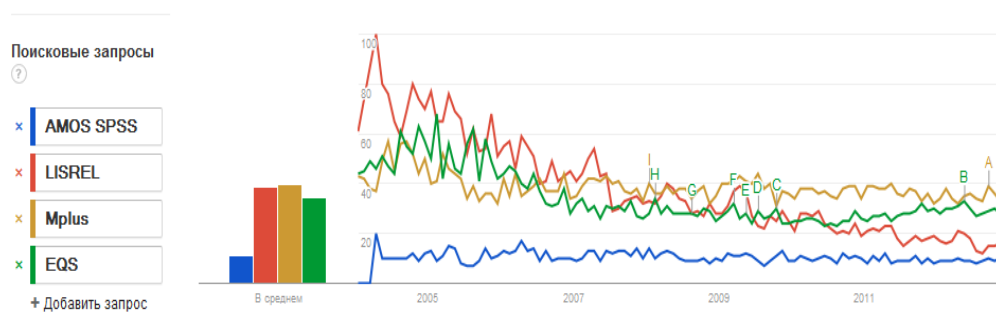


Fig 4. Analysis of popular SEM software: AMOS SPSS, Lisrel, Mplus, EQS

As Fig. 4 shows that in 2004 the leader is Lida Lisrel, whose popularity has since slightly declined, while Mplus and EQS and demonstrate stability. In recent years the situation has changed (Fig. 5). Popularity of Lisrel SPSS and Amos is almost equal.

All these tools are commercial products, though some of them have a free student version with very limited opportunities [11; 15; 16; 21].

Among free software tools those worth mentioning is OpenMx developed by th Human Dynamics Lab of Psychology Faculty of the University of Virginia [17]. OpenMx development is supported by the OpenSEM community, whose materials are intended for users of all types of software.



Fig. 5. Popularity of Lisrel and SPSS Amos

The analysis of scientific sources [1; 3; 9; 13; 31], curriculums of the leading universities [7; 8; 10; 18; 23–30] allows to distinguish the content of training of future educators to use SEM. First of all, it is the knowledge of the methodology of structural equation modeling and its special varieties - path analysis and factor analysis. Students must also learn how to use SEM for multiple groups, longitudinal data, not normally distributed data and data of other types. Students need to understand how to use SEM techniques to answer research questions in behavioral sciences, social sciences, and education. An important role in the course belongs to – formation of students’ ability to read, understand, critically evaluate and interpret scientific articles that use the SEM methodology. The aim of practical classes is to develop the skills to prepare and process data using computer programs for structural equations modelling (LISREL, M-PLUS, AMOS, OpenMx). Requirements for preliminary student training in mastering the SEM methodology involve traditional statistical methods, including regression and factor analysis, ability to work with modern statistical packages SAS and SPSS. We suggest to choose two software tools to work. First, it is AMOS, because of its popularity and connection with SPSS, which effectively became the standard in the training of sociologists. Second, the R environment, a free and open tool that includes packages with advanced methods of

analysis, including SEM. In addition, the data analysis courses that we developed for university students of various majors [5] already use SPSS and R, which ensures consistency in training.

Conclusions. The training of future researchers (PhD) requires their use of multivariate research methods in general, and the use of SEM methodologies, in particular. The use of SEM methodology promotes systematic, model and critical thinking, and allows to simulate and study the phenomena within their relationships, to understand the impact of latent factors on the phenomena studied.

The study proved the need to include the SEM tools into the PhD training courses in Ukrainian universities, singled out the content of teaching SEM methodologies, analyzes the popularity dynamics of SEM methodologies tools and appropriate software used in foreign PhD training programs, proposed the use of appropriate software (AMOS SPSS , R).

Further research direction is the creation of teaching materials for structural equation modeling as a distance course in MOODLE system for training future researchers in the field of education and social sciences.

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Моделювання структурними рівняннями як складник підготовки докторів філософії Стаття присвячена питанням підготовки майбутніх докторів філософії до використання напряму прикладного аналізу – моделювання структурними рівняннями. Проаналізовано сілабуси програм підготовки докторів філософії провідних університетів світу. Виявлено зміст навчання моделювання структурними рівняннями майбутніх науковців в галузі наук про освіту та соціальних наук. Мета курсів: застосування SEM до дослідження проблем соціальних та поведінкових наук, розуміння переваг та вад методу, його обмежень, навчання методам оцінки, ідентифікації моделей, перевірки їх придатності, інтерпретації, критичне оцінювання наукових публікацій з цієї тематики, використання статистичного програмного забезпечення для виконання SEM, підготовка звітів з дослідження у відповідності із стандартами

, які існують для досліджень та академічних публікацій. Аналізується динаміка популярності програмного забезпечення моделювання структурними рівняннями: AMOS SPSS, Lisrel, Mplus, EQS; динаміка популярності книг з тематики SEM на amazon.com. Обґрунтовується необхідність включення цих засобів в курси для майбутніх науковців ВНЗ України, які спеціалізуються в галузі освіти та соціальних наук. Ключові слова: моделювання структурними рівняннями, SEM, підготовка докторів філософії, програмне забезпечення моделювання структурними рівняннями, Lisrel, Amos, R Панченко Л. Ф., Разоренова М. В. Моделирование структурными уравнениями как составляющая подготовки докторов философии Статья посвящена вопросам подготовки будущих докторов философии к использованию такого направления прикладного анализа как моделирование структурными уравнениями (SEM). Проанализированы syllabus программы подготовки докторов философии ведущих университетов мира. Выявлено содержание обучения моделирования структурными уравнениями будущих исследователей в области наук об образовании и социальных наук. Цель курсов: применение SEM к исследованию проблем социальных и поведенческих наук, понимание преимуществ и недостатков метода, его ограниченности, обучение методам оценки, идентификации моделей, проверки их пригодности, интерпретации, критическое оценивание научных публикаций по этой тематике, использование статистического программного обеспечения для выполнения SEM, подготовка отчетов по исследованию в соответствии со стандартами, которые существуют для исследований и академических публикаций. Анализируется динамика популярности программного обеспечения моделирования структурными уравнениями: AMOS SPSS, Lisrel, Mplus, EQS; динамика популярности книг по тематике SEM на amazon.com. Обосновывается необходимость включения этих инструментов в курсы для подготовки будущих исследователей в вузах Украины. Ключевые слова: моделирование структурными уравнениями, SEM, подготовка докторов философии, программное обеспечение моделирования структурными уравнениями, Lisrel, Amos, R.

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