Unveiling the potential of structural equation modelling in educational research: a comparative analysis of Ukrainian teachers' self-efficacy

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Abstract. This article delves into the application of structural equation modelling (SEM) methodology within the realm of educational research, enabling researchers to construct comprehensive multidimensional models that elucidate the intricacies of studied phenomena and processes. Based on well-established statistical techniques such as correlation, regression, factor analysis, variance analysis, and covariance analysis, SEM methodology utilizes deductive logic to preliminarily construct a structural model of variable relationships, subsequently tested for consistency with empirical data. This study presents a comprehensive overview of diverse SEM software employed in doctoral training programs across leading global universities, while showcasing a practical example of employing SEM methodology in educational research for training PhD students. An essential aspect of SEM training for specialists involves the careful selection or acquisition of representative and valid datasets. Furthermore, this research examines the Ukrainian teacher's self-efficacy model using SEM methodology and compares the obtained results with data from the internationally renowned Teaching and Learning International Survey (TALIS). The findings underscore the lower self-efficacy levels among Ukrainian teachers, particularly within the student engagement domain, thereby shedding light on crucial aspects of teacher effectiveness and potential areas for improvement.[1]

Keywords: structure equation modelling, TALIS methodology, Ukrainian teachers, teacher's self-efficacy, PhD students, AMOS, R

1. Introduction

1.1. Setting of a problem

In Ukraine, the rise of doctoral programs has brought forth the necessity for rigorous and systematic exploration of complex phenomena. Understanding the multidimensionality inherent in educational research requires the utilization of sophisticated analytical techniques capable of uncovering causal relationships and latent factors. Structural equation modelling (SEM), a burgeoning approach in the realms of education, psychology, and social sciences, has gained significant popularity among researchers [4–6, 10, 11].

[1]This is an extended and revised version of the paper presented at the 1st Symposium on Advances in Educational Technology [15].

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This article [13] presents three key focal points for enhancing the research component within doctoral programs. Firstly, the adoption of the reproducible research principle is advocated. Secondly, the integration of multivariate models and SEM methodology is emphasized. SEM methodology, grounded in deductive logic, involves constructing preliminary structural models to assess their compatibility with experimental data. Lastly, the article advocates for a synthesis of qualitative and quantitative methods, employing triangulation techniques such as data triangulation, investigation triangulation, and theory triangulation. The proposed curriculum for doctoral students encompasses courses on Reproducible Research and Multivariate Methods in Scientific Research.

The core emphasis of this article revolves around the significance of training future doctoral candidates in the effective utilization of SEM methodology within educational research. By equipping scholars with this powerful analytical tool, we can advance the boundaries of educational research and unlock new insights into the complex dynamics of learning and instruction.

The surge in popularity of structural equation modelling (SEM) methodology is evident from our empirical investigation. At the request of "structural equation modeling" to search books on Amazon.com (as of March 16, 2013), we obtained 59 items, the graph of which is clearly shown in figure 1. In the center of the graph (figure 1, on the left), where 5 subgraphs can be observed, there is the fifth edition of the bestseller, *Principles and Practice of Structural Equation Modeling* by Kline [6]. The companion site of this publication provides methodological support and offers download syntax, data and source files for all sample books for execution in three environments EQS, LISREL and Mplus, and a comparison of simulation results. A similar experiment, conducted on March 28, 2019 (figure 1, on the right), shows interest growth in structural modeling; we have 157 items. Interestingly, the fourth edition of the same bestseller has the biggest rating there.

Figure 1: Books on "structural equation modeling", Amazon.com, year 2013 versus 2019.

In this study, our focus lies in addressing the significant challenge of effectively training PhD students in the utilization of the Structural Equation Modeling (SEM) methodology. Building upon prior research by various authors, notable outcomes have been achieved. These include the elucidation of the content pertaining to simulation training using structural equations within the field of education, as well as the analysis of the dynamic aspects associated with software simulation utilizing structural equations. Furthermore, the indispensable nature of incorporating such tools within the curricula of educational and social sciences programs offered by Ukrainian higher educational institutions has been firmly established [12].

To gain a comprehensive understanding of the existing landscape, we conducted an examination of the syllabi of PhD-level SEM courses at renowned universities. Notable institutions such as the University of Vaasa in Finland, the University of Mannheim, Iowa State University, Brown University, the University of Leuven, the School of Education at the University of Pittsburgh, and Oslo University were among those considered in this analysis.

In addition, we drew upon the esteemed Princeton Review's "Gourman Report of Graduate Programs" [17] to identify the leading PhD programs in sociology. Our investigation revealed that these programs emphasize the inclusion of courses on structural equation modeling as an essential component. Table 1 provides a comprehensive summary of the various SEM software employed in the training of doctoral candidates at prestigious universities worldwide.

Upon careful analysis of the syllabi presented in table 1, it becomes evident that the courses are predominantly structured as seminars. These seminars encompass a combination of lectures, group discussions, software application, and result interpretation. The course materials are made available through the Blackboard or Moodle learning management systems. The credit allocation for these courses ranges from 1 to 6 credits, with introductory courses typically accounting for 1–3 credits and advanced courses ranging from 4 to 6 credits. These courses are offered as part of the doctoral training programs in various fields such as pedagogy, psychology, sociology, statistics, information systems and business, public health, and sports, among others. Both proprietary and free software are utilized, with most courses designating one software tool as the primary tool and another as an auxiliary tool. However, some courses make extensive use of multiple software tools.

To illustrate the evaluation process within such courses, we provide an example from a specific course [16]. The assessment components consist of statistical software-based homework, accounting for 8% of the final grade, critical reviews of articles related to the topic (four reviews, each spanning 4–5 pages), contributing 30% to the final grade, and statistical analysis (four reports, each spanning 12–15 pages), constituting 62% of the final grade. The evaluation criteria for the critical reviews are explicitly outlined, including aspects such as explaining the fundamental model evaluated by the author (20% of the grade), discussing critical errors made by the author (40%), and elucidating the correct estimation of causal effects (40%). Some programs also include an exam and a final project, which serves as a miniature study on the application of SEM.

The primary objectives of SEM courses are defined as follows [14]: employing structural equation modeling to examine issues within social and behavioral sciences, comprehending the strengths, limitations, and flaws of the methodology, teaching assessment methods, identification of models, testing their validity, interpretation of results, critically evaluating scientific publications in this domain, utilizing statistical software for performing structural equation modeling analyses, and preparing research reports adhering to research standards.

One crucial aspect in preparing specialists to utilize SEM is the selection or acquisition of representative and valid datasets. In our educational setting, we provide our students with survey data collected from Ukrainian teachers [1, 18, 20].

Table 1
Software in SEM courses.

Course name	Software						
	AMOS SPSS	EQS	Mplus	Lisrel	Open Mx	SAS	R
"Structural equation modelling in educational research", University of Amsterdam			+	+	+		
"Latent Structural Equation Modeling", University of Vaasa, Finland	+		+	+		+	+
SEM1, University of Oregon	+		+				
"Structural equation modelling using LISREL and EQS" (SEM PhD workshop)		+		+			
"Structural Equation Modeling in the IS Discipline", University of Mannheim	smart PLS						
"Structural equation models for social and behavioral research", Iowa State University							
"Structural Equation Models in the Social Sciences", University of Brown				+			
"Causal analysis and structural equation modeling"			+ Stata				
"Structural Equations", University of Leuven, PhD in Statictics				+			
"Structural Equation Modeling", School of Education University of Pittsburgh			+		+		
"Structural equation modeling: Longitudinal models and multi-group models", University of Oslo			+				
"Building and Testing Structural Equation Models In the Social Sciences", University of Michigan	+	+		+			
"An introduction to structural equation modelling", Doctoral college of Ulster University							
"PhD-M: Structural Equations Modeling", University of Vienna				+			
PSY9140 – "Structural Equation Modelling", Oslo university			+				+
PSY8006 – "Introduction to Structural Equation Modeling (with MPlus)", Norwegian university of science and technology			+				
Introduction to Structural Equation Modeling (SEM), PhD School of Copenhagen Business School			+				

On August 31, 2017, the Ukrainian Association of Educational Researchers conducted the All-Ukrainian monitoring study titled "Teaching and Learning Survey on Principals and Teachers of Secondary Education Institutions", based on the TALIS methodology [21]. This study was part of the larger project "Teacher" and "Education Reform: Quality Assessment in an International

Context", implemented by the All-Ukrainian Foundation "Step by Step" with the support of the Ministry of Education and Science of Ukraine [20]. The study involved the participation of 3,600 teachers and 201 school principals from 201 schools, representing all regions of Ukraine. In accordance with OECD policy, the study results are publicly accessible.

The objective of our article is to demonstrate the application of SEM methodology in educational research for PhD students. In our case study, we utilize survey data obtained from Ukrainian teachers to examine the model of teacher self-efficacy using SEM methodology and compare the results with the research data from the global teacher survey, TALIS.

1.2. Related works

The methodology of structural modeling, particularly in the context of social sciences, has gained significant recognition on a global scale. The fundamentals of structural modeling have become an integral component of training for researchers specializing in social sciences [14]. The concepts of structural modeling as applied to psychology have been explored in works by Mitina [10], Nasledov [11]. Chornyi [4] has studied the utilization of SEM with a focus on economic research. Regrettably, in Ukraine, the adoption of structural modeling in educational and social studies, including the training of researchers at universities, remains limited.

Several research studies have addressed the application of the SEM methodology to educational data, specifically focusing on TALIS 2013. Badri et al. [2] reviewed a structural equation model that examines the determinants of the perceived impact of teachers' professional development, with a particular emphasis on the Abu Dhabi context. Liu, Bellibas and Printy [9] explored how school context and teacher characteristics predict distributed leadership. Scherer et al. [19] conducted a review on the invariance of teachers' sense of self-efficacy measured across different countries. These studies shed light on the various aspects of applying SEM methodology to educational data and provide valuable insights into the field.

2. Results of the study

TALIS (Teaching and Learning International Survey) stands as one of the most esteemed international comparative education projects. This initiative, conducted by a research consortium under the Organization for Economic Cooperation and Development (OECD), has been dedicated to studying the working conditions and environments of school teachers since 2008. The first wave of the TALIS study in 2008 involved the participation of 24 OECD countries and partner countries, followed by 34 countries in the second wave in 2013. For the upcoming wave in 2018, 44 countries are expected to participate [20, 21].

The All-Ukrainian monitoring survey of teaching and learning among school principals and teachers in general educational institutions, based on the methodology of the All-Ukrainian research following the TALIS methodology, exemplifies the utilization of international instruments to explore the national educational landscape and identify the position of the Ukrainian teacher community within the international educational context. The objective of this research is to identify and analyze the socio-demographic and professional characteristics of Ukrainian teachers and academic staff, as well as the school environment, using reliable and comparable metrics [20].

In 2017, a total of 3,600 teachers from grades 5 to 9 in secondary schools (ISCED level 2) and 201 school principals representing 201 schools participated in the survey. The sampling error for simple random sampling is 1.6%, while the school sample selection error, accounting for the design effect, is 2.3%.

From the Ukrainian teacher survey dataset [1], we selected 3,477 data entries with complete information across 12 variables that pertain to teacher self-efficacy (table 2).

Table 2
Variables of teacher's self-efficacy.

Variable name	Content
TT2G34A	Get students to believe they can do well in school work
TT2G34B	Help my students value learning
TT2G34C	Craft good questions for my students
TT2G34D	Control disruptive behavior in the classroom
TT2G34E	Motivate students who show low interest in school work
TT2G34F	Make my expectations about student behavior clear
TT2G34G	Help students think critically
TT2G34H	Use a variety of assessment strategies
TT2G34I	Provide an alternative explanation, for example, when students are confused
TT2G34J	Implement alternative instructional strategies in my classroom
TT2G34K	Get students to follow classroom rules
TT2G34L	Calm down a student who is disruptive or noisy

Self-efficacy, as defined by Bandura [3], refers to an individual's personal judgment regarding their ability to effectively perform the necessary actions to navigate future situations. Bandura [3] identifies four sources that contribute to efficacy beliefs: 1) mastery experiences, 2) vicarious experiences, 3) verbal persuasion, and 4) emotional and physiological states.

In the context of professional teachers, self-efficacy can be understood as an individual's perception of their own capability to mobilize motivation, cognitive resources, and behavioral actions required to effectively manage a situation and achieve desired goals [3, 7, 8].

Within the TALIS framework, the model for teacher self-efficacy comprises three components: self-efficacy in classroom management, self-efficacy in instruction, and self-efficacy in student engagement.

To explore the structure of the data, we will conduct a factor analysis. The Kaiser-Meyer-Olkin measure (0.902) and the significant Bartlett's Test of Sphericity (13308, $p < 0.001$) indicate that factor analysis is an appropriate method for analyzing this data. The scree plot displayed in figure 2 indicates the presence of three factors.

Let us examine the rotated component matrix (table 3). The matrix reveals the relationship between the attributes and the factors based on high factor loadings.

Upon analysis, it becomes evident that the first factor is strongly associated with class management, as indicated by the high factor weights of the corresponding attributes. This factor represents the teacher's self-efficacy in effectively managing the classroom environment.

The second factor is primarily related to student engagement. The attributes associated with this factor reflect the teacher's self-efficacy in fostering student involvement and creating an

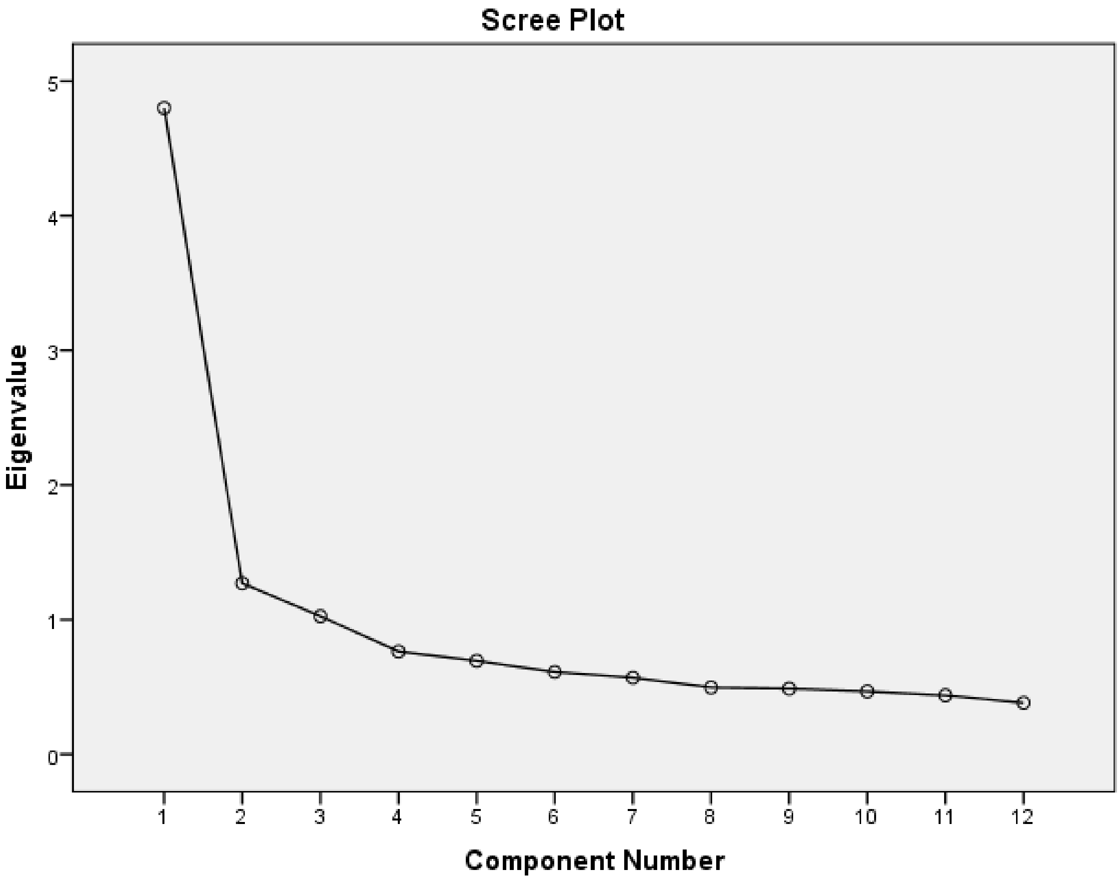

Figure 2: Scree plot: a line plot of the eigenvalues of factors.

engaging learning environment.

The third factor is predominantly connected to instruction. The attributes linked to this factor signify the teacher's self-efficacy in delivering effective instruction and facilitating student learning.

Overall, the rotated component matrix provides insights into the underlying structure of the data, indicating that the three factors correspond to class management, student engagement, and instruction, respectively.

Indeed, upon closer observation of the rotated component matrix (table 3), we can note that the variable "Craft good questions for my students" demonstrates a higher association with the factor labeled "Student engagement" rather than the factor labeled "Instruction". This suggests that this particular attribute is more strongly linked to the teacher's self-efficacy in fostering student engagement rather than instructional practices.

Furthermore, the cumulative variance explained by the three factors is 59.1%, as indicated in table 4. This means that these three factors collectively account for approximately 59.1% of the variability in the dataset.

Scientists have outlined a series of steps in the application of Structural Equation Modeling

Table 3
Rotated component matrix.

	Factor 1: Class management	Factor 2: Student engagement	Factor 3: Instruction
Control disruptive behavior in the classroom	.795		
Calm a student who is disruptive or noisy	.773		
Get students to follow classroom rules	.765		
Make my expectations about student behavior clear	.596		
Help my students value learning		.816	
Get students to believe they can do well in school work		.764	
Motivate students who show low interest in school work		.644	
Help students think critically		.448	
Craft good questions for my students		.443	
Provide an alternative explanation. for example. when students are confused			.785
Implement alternative instructional strategies in my classroom			.736
Use a variety of assessment strategies			.730

Table 4
Total variance explained.

Component	Rotation sums of squared loadings		
	Total	% of Variance	Cumulative %
1	2.571	21.425	21.425
2	2.313	19.274	40.698
3	2.211	18.429	59.127

(SEM) [6, 11]. These steps provide a structured approach to utilizing SEM in research:

1. *Model formation*: In this step, the researcher conceptualizes the graphical representation of the relationships among variables and latent constructs. They determine which parameters should be fixed and which should remain free.
2. *Model identification*: The researcher establishes the identifiability of the model, ensuring that the parameters can be estimated from the available data.
3. *Model evaluation*: This step involves assessing the fit of the model to the data using various fit indices and statistical tests. The goal is to determine how well the proposed model aligns with the observed data.
4. *Checking model consistency*: The researcher examines the internal consistency of the model, ensuring that it is coherent and logical in explaining the relationships between variables and constructs.
5. *Model correction*: If necessary, the researcher makes adjustments to the model by adding new connections or removing insignificant links. This iterative process aims to refine the model and improve its overall fit to the data.

Now, let us construct a confirmatory factor analysis model using AMOS in SPSS (refer to figure 3). This model will help to analyze the relationships and validate the measurement of latent constructs.

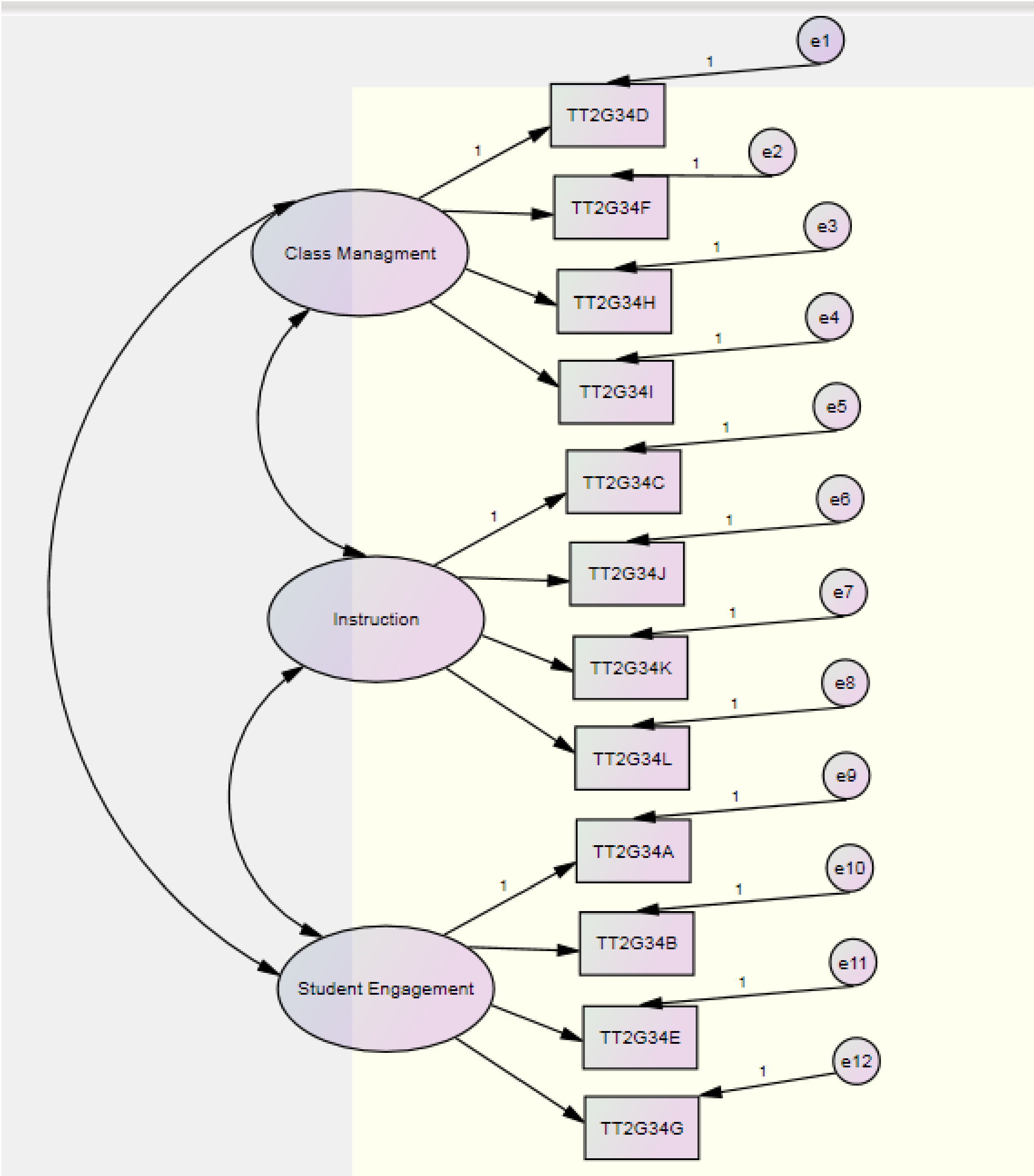

Figure 3: Initial teacher's self-efficacy model in AMOS SPSS.

You can see the resulting teacher's self-efficacy model in the figure 4.

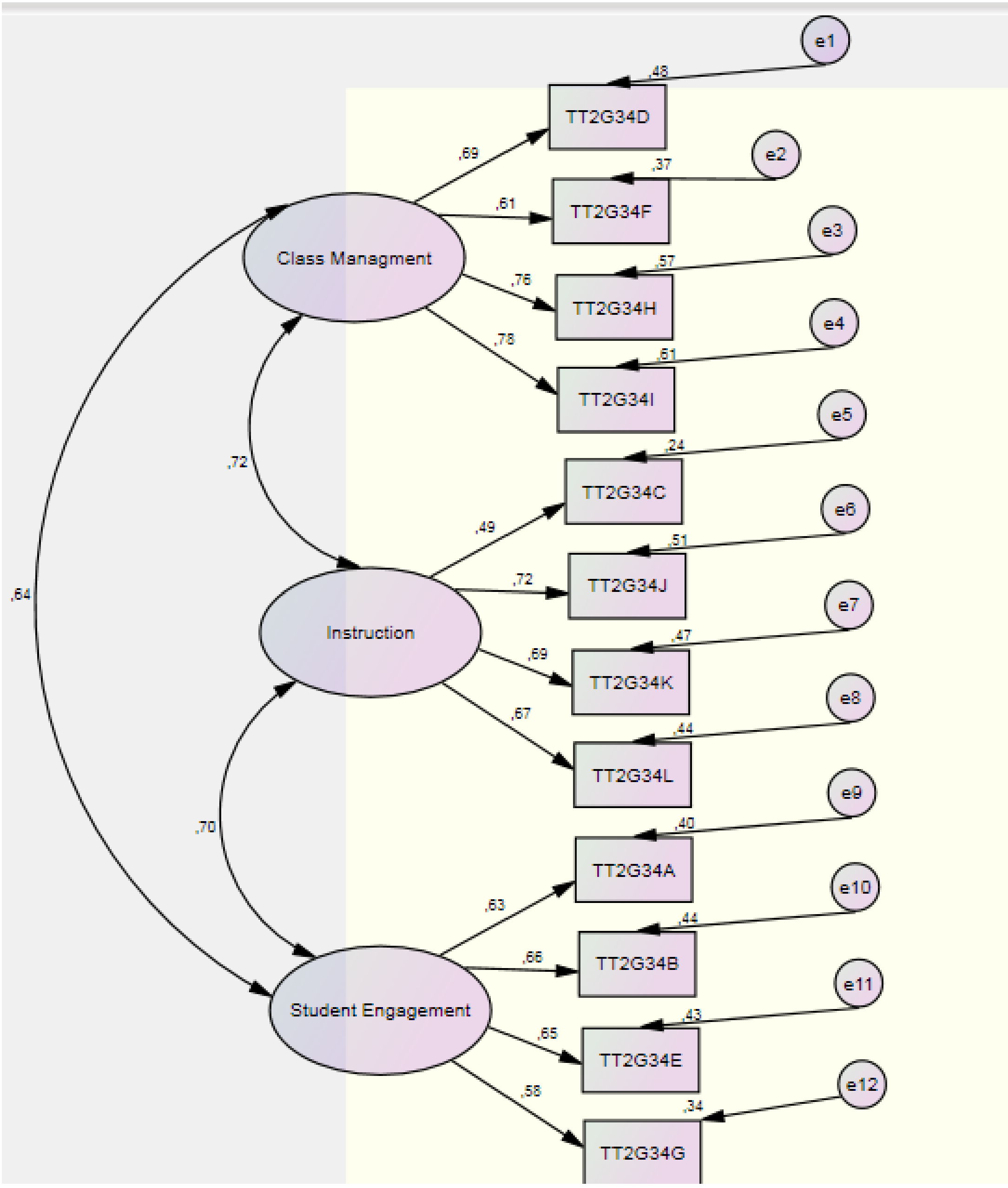

Figure 4: Resulting teacher's self-efficacy model in AMOS SPSS.

We got the following results:

- The number of distinct sample moments is 78, while the number of distinct parameters to be estimated is 27.
- The degrees of freedom can be calculated as 78 − 27 = 51.

In terms of model fit, the RMSEA criterion indicates that the model is coherent with the data, as the value of 0.07 is less than the recommended threshold of 0.08. This suggests that the model aligns well with the observed data.

Using the data from the study [20], a comparison was made between the indicators of self-efficacy among Ukrainian teachers and teachers worldwide (see table 5 and figure 5). The graph illustrates that the self-efficacy of Ukrainian teachers tends to be lower, particularly in the domain of student engagement. Specifically, there are notable differences in the variables ‘Get students to believe they can do well in school work” (with a difference of 26.4%), “Help my students value learning” (with a difference of 26%), and “Motivate students who show low interest in school work” (with a difference of 19.4%). These findings suggest that Ukrainian teachers perceive lower levels of self-efficacy in fostering student engagement compared to their international counterparts.

Table 5
Indicators of self-efficacy of teachers in Ukraine and in the world (%).

Variables	Ukrainian teachers	TALIS	Difference
A. Get students to believe they can do well in school work	59.4	85.8	26.4
B. Help my students value learning	54.7	80.7	26
C. Craft good questions for my students	82.6	87.4	4.8
D. Control disruptive behavior in the classroom	85	87	2
E. Motivate students who show low interest in school work	50.6	70	19.4
F. Make my expectations about student behavior clear	68	91.3	23.3
G. Help students think critically	69.5	80.3	10.8
H. Use a variety of assessment strategies	77	89.4	12.4
I. Provide an alternative explanation. for example. when students are confused	78.5	84.8	6.3
J. Implement alternative instructional strategies in my classroom	87.8	81.9	-5.9
K. Get students to follow classroom rules	92.9	92	-0.9
L. Calm a student who is disruptive or noisy	72	77.4	5.4

As part of the research, PhD students can be encouraged to analyze the results of the recently published TALIS 2018 survey [17]. TALIS 2018 identifies several factors that are associated with teacher self-efficacy. These factors include:

1. Teacher characteristics: Years of experience as a teacher
2. Index of classroom disciplinary climate
3. Participation in any induction activities at the current school
4. Inclusion of team teaching with experienced teachers in induction activities at the current school
5. Positive impact of professional development activities on teaching practice in the 12 months prior to the survey
6. Index of workplace well-being and stress
7. Fixed-term contract duration: Less than or equal to one school year

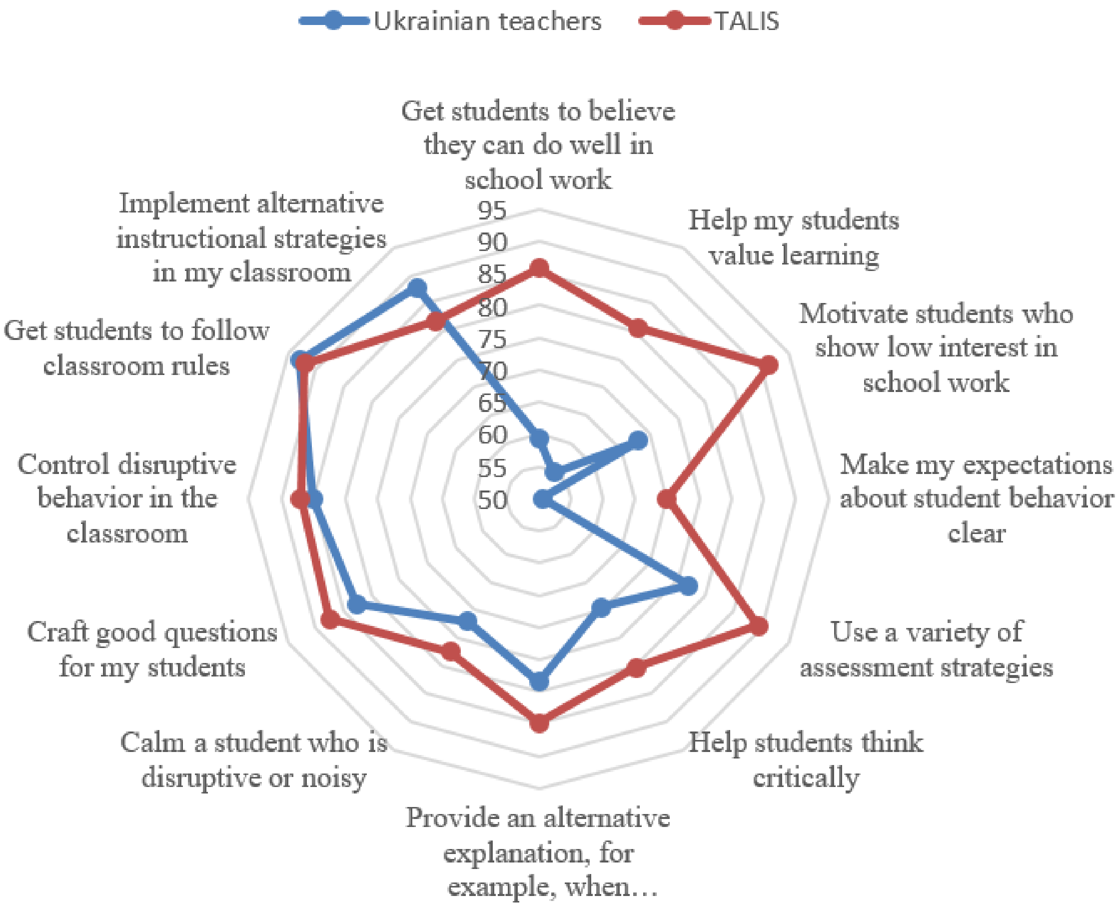

Figure 5: Comparison of teachers' self-efficacy in Ukraine and in the world.

8. Index of professional collaboration
9. Index of target class autonomy

It is important to note that the relationship between these factors and teacher self-efficacy may not be applicable to all countries. The variations in the relationship between these factors and teacher self-efficacy across different countries can be observed in Table 6. This suggests that contextual factors may influence the extent to which these factors contribute to teacher self-efficacy in different educational settings.

Building an SEM model incorporating the factors of teacher's self-efficacy according to TALIS 2018 can indeed be an interesting task for PhD students. By considering the factors identified in TALIS 2018 and their relationships with teacher self-efficacy, the students can develop a comprehensive model that examines the underlying structure and dynamics of teacher self-efficacy.

To begin, the students can specify the latent constructs for each factor identified in TALIS 2018, such as teacher characteristics, classroom disciplinary climate, induction activities, professional development, workplace well-being, contract duration, professional collaboration, and target

Table 6
Factor of self-efficacy of teachers in TALIS 2018 and number of countries and percentage of countries with positive and negative relation (%).

Factor	N+	%+	N-	% -
Teacher characteristics: years of experience as a teacher	29	60.4	0	0
Index of classroom disciplinary climate	0	0	45	93.8
Took part in any induction activities at current school	25	52.1	0	0
Induction activities at current school included team teaching with experienced teachers	35	72.9	0	0
Professional development acitivities in the 12 months prior to the survey did have a positive impact on teaching practice	33	68.8	0	0
Index of workplace well-being and stress	0	0.0	42	87.5
Fixed-term contract: less than or one school year	0	0.0	15	31.3
Index of professional collaboration	46	95.8	0	0
Index of target class autonomy	47	97.9	0	0

class autonomy. These latent constructs can be represented by observed indicators or variables related to each factor.

Next, the students can hypothesize the relationships between these latent constructs and teacher self-efficacy. For example, they can propose that years of experience as a teacher, participation in induction activities, and positive professional development experiences positively influence teacher self-efficacy, while factors like workplace stress and fixed-term contracts may negatively impact self-efficacy.

The students can then use SEM techniques, such as confirmatory factor analysis and structural equation modeling, to estimate the parameters of the proposed model and assess its fit to the data. This analysis will help determine the strength and significance of the relationships between the latent constructs and teacher self-efficacy, providing valuable insights into the factors that contribute to teacher self-efficacy in the context of TALIS 2018.

By engaging in this task, PhD students can gain practical experience in model building, data analysis, and interpretation of results, while also contributing to the understanding of teacher self-efficacy and its determinants in the specific context of TALIS 2018.

3. Conclusions and perspectives of further research

In conclusion, the use of structural equation modeling (SEM) methodology in educational research and the training of PhD students has several important implications. First, it allows for the study of complex educational phenomena and the evaluation of educational innovations in different contexts. SEM enables researchers to model and analyze the interrelationships between latent factors, contributing to a better understanding of the underlying mechanisms and processes in education.

Furthermore, the availability of representative and valid data sets is crucial for training specialists in SEM. The use of freely accessible and well-documented data sets, such as the All-Ukrainian survey data from Ukrainian teachers, provides students with practical examples and opportunities for comparative studies with international data, such as the TALIS survey.

The case study on teacher's self-efficacy using SEM methodology and comparing the results with TALIS survey data revealed interesting findings, highlighting lower self-efficacy among Ukrainian teachers, particularly in the student engagement aspect. This emphasizes the importance of addressing and improving teacher self-efficacy in the Ukrainian educational context.

Moving forward, it is essential to develop teaching materials and methodological support for SEM modeling, including computer workshops using software like AMOS and R. These resources will facilitate the training of researchers in the field of pedagogy and social sciences, equipping them with the necessary skills to apply SEM in their research projects.

Additionally, advocating for the inclusion of SEM in higher education research can lead to a more comprehensive and rigorous approach to studying educational phenomena. By incorporating SEM methodology into the research practices of higher education institutions, researchers and educators can enhance their analytical capabilities and promote evidence-based decision-making in education.

In summary, the utilization of SEM methodology, the exploration of representative data sets, and the integration of SEM in higher education research can contribute to the advancement of educational research and the training of PhD students. These efforts promote reproducible research, multivariate analysis, and triangulation, enabling researchers to gain deeper insights into educational phenomena and inform evidence-based practices in the field of education.

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