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Identification and Validation of the Dimensions and Components of Teachers' Professional Learning Networks Model: A Mixed-Method Study

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Abstract

Professional learning networks (PLNs) are an emerging research area that requires further exploration. We need more information about the basic processes of teachers' learning in these networks. The present study aimed to identify and validate the dimensions and components of the professional learning network model of elementary school teachers in Tabriz. In this study, a mixed method (qualitative-quantitative) of sequential exploratory type was used. In the qualitative part of the research, the required data were collected using the meta-synthesis method, and in this regard, 35 articles were purposefully selected and included in the analysis. Also, the fuzzy Delphi method was used to confirm and screen the findings, and the final weight of the desired dimensions and components was obtained using the SWARA method. In the quantitative part, to examine the fit of the identified model, the research components were collected in a questionnaire and distributed among elementary school teachers in Tabriz using cluster and stratified sampling methods. The data in this section were analyzed using confirmatory factor analysis in SPSS26 and AMOS26 software. In total, 308 codes were extracted from the studied sources. These codes were included in 15 concepts and 3 main categories: individual, group, and organizational, and a model of teachers' professional learning networks was formed. The concepts of valuing people, the occurrence of change, and progress were introduced as the most important. The fit indices of the measurement model show that the identified dimensions and components had a good fit. The findings show that networks are effective for realizing teachers' learning and improving teaching-learning processes.

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Introduction

Teachers are increasingly utilizing digital technologies to foster and expand their professional learning networks. A professional learning network can be thought of as "a system of interpersonal connections and resources that support informal learning." While many teachers assert that they benefit from professional learning networks, much is still unknown about how teachers perceive these networks. Understanding how teachers learn from these networks and how this affects student teaching and learning requires further research (Trust et al, 2016). The expansion of networks as a strategic change is occurring at a very rapid pace, irrespective of its effectiveness in education systems worldwide (Rincón-Gallardo & Fullan, 2016). Networks are interdependent structures within which processes occur that explore new ways of learning and collaboration between individuals and institutions (Rauch, 2013). As educational issues become more complex, teachers must engage in ongoing professional development. (Oddone et al., 2019, p.103). Many researchers assert that teachers require opportunities and activities for professional development and ongoing learning to enhance their performance and positively influence student learning. (Darling-Hammond et al, 2009; Kennedy, 2016; Timperley & Alton-Lee, 2008, p.341 & Van den Bergh et al, 2014, p.797). Teachers in schools, to improve their teaching methods, often participate in formal professional development activities such as workshops, lectures, seminars, etc. However, this traditional form of professional development has been criticized for its lack of success (Borko, 2004 & Kennedy, 2016). Current professional development approaches may not meet the needs of contemporary teachers (Oddone et al, 2019, p.102). And often have limited impact, in these approaches, there is a persistent discrepancy between what is known to be effective and what teachers experience (Calvert, 2016). Historically, formal forms of professional development included professional seminars and conferences presented by an expert (Duncan-Howell, 2010). These traditional forms of professional development have often been criticized for their lack of continuity and coherence and lack of long-term impact on education (Anderson & Henderson, 2004 & Curwood, 2011). Since then, other forms of professional development have emerged, including continuing professional learning in schools (Webb et al, 2005), learning communities in schools (Curwood, 2011 & Lieberman et al, 2011), online teacher forums (Duncan-Howell, 2010), and blended models of professional development (Anderson & Henderson, 2004). However, adapting to new approaches to professional development has been impractical for many schools, and traditional forms of professional learning continue to exist (Duncan-Howell, 2010; Lieberman et al, 2011). These challenges need to be addressed if teacher professional development is to be effective.

One of the basic developments in education in recent years has been the growth of networking in the school systems (Schnellert & Butler, 2021, p.100 & Gatz & Akiva, 2024, p.91-92). By examining the research conducted in this field, the importance of cooperation between educational experts in classes, schools, regions, and educational systems is widely evident (Campbell, 2017, p.3-4; Darling-Hammond et al, 2009, p.11). In simple words, networks are groups of people and organizations that have direct and indirect connections between them (Chapman & Muijs, 2014). One of the recent views on the concept of networking in education is: "A large group of people with similar interests or concerns who interact and exchange knowledge, who strive for mutual assistance, support, and expansion of learning (Kools & Stoll, 2016, p.5). Díaz-Gibson et al (2017) use the term "participatory educational networks" to achieve educational goals at the community level based on joint actions and cooperation between schools and social organizations. From this point of view, network cooperation creates spaces where different educational and social communities can be enriched by sharing content, experiences, and information. In the field of networking in education, experiences, projects, and policies are being implemented all over the world (Akiva & Robinson, 2022, p.69). Therefore, researchers have taken a deeper look at how to create cooperation networks between school systems (Leithwood, 2019). It should be acknowledged that the expansion of networks as a strategic change is taking place all over the world at a very fast pace, regardless of its effectiveness (Rincón-Gallardo & Fullan, 2016).

Due to the shortcomings of traditional professional development strategies, some teachers join

professional learning networks based on their interests, goals, and professional needs. Professional learning networks are exclusively defined systems of interactions between people, spaces, and tools that support professional learning and growth (Trust et al, 2016, p.22). Teachers' participation in professional learning networks can create opportunities for collective learning (Desimone, 2009, p.184; Timperley & Alton-Lee, 2008, p.324 & Van den Bergh, 2014, p.786). Professional learning networks can complement traditional professional development learning experiences, while traditional professional development strategies emphasize content knowledge (Kennedy, 2016, p.27 & OECD, 2014, p.130); And the participants have less independence of action (Bill & Melinda Gates Foundation, 2014). Brown and Poortman defined professional learning networks as a group of related educators who work together to strengthen their relationships and interact to improve practices in the school system. These interactions include lesson design, study groups, and professional development networks between teachers. According to these authors, these networks are usually different in their composition, nature, and focus and are made up of teachers and school administrators from different regions, in many cases, networks can be formed collaboratively and include Collaborate with foreign researchers, and they all have in common is that learning and progress are at their core (Brown & Poortman, 2018, p.1). Many pieces of evidence show that professional learning networks are considered an important factor in creating change and innovation (Bryk et al, 2015; Harris & Jones, 2010, p.174; Timperley et al., 2014 & Trust et al, 2016). Overall, there is a rich body of research-based literature on teacher collaboration and the networks that can be designed and created, and it would be useful to interpret current and future research on the function and dimensions of teacher professional learning networks. However, more time is needed to determine how beneficial professional learning networks are and how teachers will collaborate and participate in this competitive educational environment (Azorín, 2018).

The United Kingdom considers networking as an integral part of its educational policies and allocates significant funds for the development of collaborative approaches between schools (Chapman, 2008, p.404; Chapman & Muijs, 2013, p.202 & Katz & Earl, 2010, p.27). Evidence shows that there are networks in the Australian education system where teachers, administrators, educational researchers, policy-makers, and educational community activists all participate (Ladwig, 2014, p.327). Elsewhere, the report "The State of Professional Teacher Education in Canada" shows that collaborative learning experiences within and between schools are valuable and common and that there are extensive professional networks among schools (Campbell et al., 2016, p.70). In the United States, there are many examples of networking among schools that reflect the political and social demands that exist in this field (Spring et al, 2017). Austria is another example where collaborative activities through networking are seen in its schools (Rauch, 2016, pp. 36-37). Researchers in Finland suggest that it is possible to improve education through networking (Sahlberg, 2011).In this regard, the Belgian government created school networks in 1998 to achieve more efficient use of public resources, rationalizing study programs, improving student outcomes, and increasing cooperation between educational districts (Feys & Devos, 2015, p.739).In the Netherlands, not only do schools cooperate, but they also support the processes of social organizations and public services (Muijs, 2015). Similarly, the study published in the Netherlands by Van den Beemt et al shows that learning in networks is focused as a form of professional learning for teachers (Van den Beemt et al, 2018, p.32).In Chile, there is also networking among schools, and the progress that comes from this area is supported (Gonzalez et al, 2017).In Spanish schools, there is also a wide network between schools that helps to develop the collective capacity of teachers (Chapman & Sammons, 2013).

A professional learning network connects people and resources for informal professional learning. Although a collection of evidence describes the nature of professional learning networks (Moreillon, 2016; Nussbaum-Beach, 2013 & Warlick, 2009), fewer studies have investigated teachers' interactions through professional learning networks (Prestridge, 2017; Prestridge, 2019 & Trust et al, 2016, p.17). Recent studies show the shift towards self-directed and interest-based professional learning and reveal the potential of professional learning networks with a dynamic and diverse nature to meet the needs of teachers seeking professional learning. (Oddone et al, 2019, p.103). A growing body of research examines how teachers learn through online and offline professional interactions that lead to the creation of communities of practice and professional learning communities (Cochran-Smith & Lytle, 1999 & Macià & García, 2016, p. 3; Stoll et al, 2006) and network learning communities (Katz & Earl, 2010; Judy et al, 2018, p.383 & Mackey & Evans, 2011) is among them. There has been a lot of attention and research on

the creation of professional learning networks in schools and educational institutions; however, many administrators and teachers still have little information about the patterns of professional learning networks and their impact on education. and learning (Vangrieken et al, 2017). Therefore, school administrators and teachers need to recognize these networks as a mechanism for school progress (Banerjee et al, 2017). The importance of studying professional learning networks and how their dimensions affect the success of the school and the development of the educational culture and collective learning of the school is very important (Broadley et al, 2019). Although the research in this field provides the need for further studies, because in addition to the fact that more strengths and weaknesses of these networks are identified for the beneficiaries, Ambiguous and unknown things will also be clarified (Draper, 2014). The notion that schooling is professionalized through participation and collaboration is a compelling concept, and there is now a growing body of research supporting this idea (Chapman & Hadfield, 2010 & Brown et al, 2021). However, this topic is still in its relative infancy, and much more needs to be learned about the realities of collaborative activities within and between schools (Ronfeldt et al, 2015). Professional learning networks are a relatively new field that needs further research, and their components need to be addressed with greater conceptual clarity (Daly & Stoll, 2018). Research on professional learning networks aims to understand how individuals within these networks learn through relationships. On the other hand, research has also addressed the processes, influencing factors, and outcomes of various types of professional learning networks (Vygotsky, 1978). We need more information about the underlying processes of teacher learning in professional learning networks and to understand how key dimensions and features of professional learning networks contribute to teacher learning, especially since little research has been conducted in this area (Prenger et al, 2021). And the question of “how teachers and educational leaders learn in professional learning networks?" remains largely unanswered (Pedersen et al, 2024). To understand how professional learning networks play a role in the productivity of elementary teachers and how they work, their patterns should be studied first of all. Therefore, this research seeks to answer these questions: What are the dimensions and components of the teachers' professional learning network model? How are the dimensions and components of teachers' professional learning networks prioritized? And what is the degree of appropriateness of the provided model? This review makes it possible to clarify complex issues about professional learning networks.

Research methodology

This research is applied research in terms of its purpose, and in terms of the data collection method, it is considered descriptive research. A mixed method (qualitative-quantitative) has been used to collect data. In the qualitative phase, the meta-synthesis method was used to identify categories, concepts, and codes. The six-step model (Sandelowski & Barroso, 2006) was used to find, select, evaluate, and combine the results of previous research. In the following, the fuzzy Delphi method was used to confirm and screen the findings. The identified components were designed in the form of a questionnaire to get the opinion of experts, and the experts expressed their agreement through Linguistic expressions. Since the different characteristics of people affect their subjective interpretations of qualitative variables, by defining the scope of qualitative variables, the experts answered the questions with the same mentality. These variables are defined according to Table 1 of triangular fuzzy numbers.

Table 1: triangular fuzzy numbers for five-point scale

Linguistic expressions	Fuzzy number	Deterministic fuzzy numbers
Very Important (VI)	(0/75, 1, 1)	0/75
Important (I)	(0/5, 0/75, 1)	0/5625
Moderately Important (MI)	(0/25, 0/5, 0/75)	0/3125
Unimportant (U)	(0, 0/25, 0/5)	0/0625
Very Unimportant (VU)	(0, 0, 0/25)	0/0625

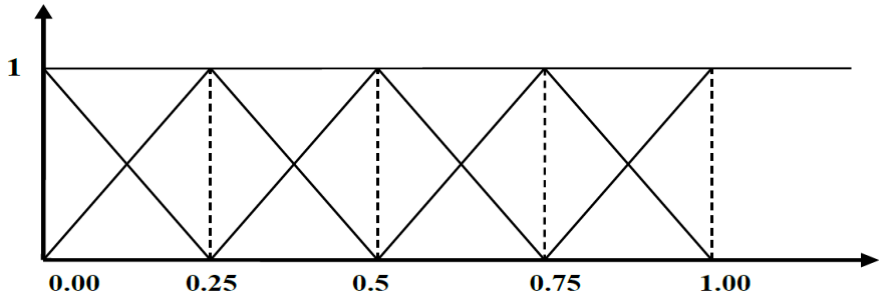

Figure 1. triangular fuzzy numbers for five-point scale

To confirm and screen the indicators, the triangular fuzzy values of the experts' opinions were first calculated, and then the fuzzy average for the respondent's opinions was calculated with the help of the following equations.

(1) $\tilde{\tau}_{ij} = (\alpha_{ij}, b_{ij}, c_{ij}), \quad i = 1,2,3,...,n \quad j = 1,2,3,...,m$

(2) $a_j = \sum \frac{a_{ij}}{n}$

(3) $b_j = \sum \frac{b_{ij}}{n}$

(4) $c_j = \sum \frac{c_{ij}}{n}$

In the above equations, the index i refers to the expert, and the index j refers to the decision-making index. Equation (5) was used to calculate the de-fuzzified value of the average fuzzy numbers.

(5) $Crisp = a + \frac{c-b}{4}$

Controlling validity and reliability in the fuzzy Delphi method is challenging. The Delphi method collects data and factors qualitatively, which means their reliability and validity cannot be determined using conventional or quantitative methods. As a result, qualitative methods are employed. In qualitative research, achieving validity is also linked to achieving reliability. Research audit strategies offer researchers reliability and validity, including:

1- Researcher sensitivity: The researcher's creativity, sensitivity, continuous analysis, expertise, and flexibility in the research process. 2- Methodological coherence: It means the alignment between the question and the elements of the research method. As a result, the research process is carried out in a round-robin manner with continuous review and analysis. 3- Sampling adequacy: Instead of referring to various individuals who may not have the necessary information for the researcher, experts are consulted; therefore, sampling occurs deliberately and selectively. Referring to experts continues until the researcher reaches theoretical saturation (consensus) and concludes that nothing new will be discovered. 4- Simultaneous data collection and analysis: During the research, ideas come to the researcher's mind that are reaffirmed in new data and may even lead to revisions to previous data and methods (Danaei Fard & Mozaffari, 2008). In this study, the validity and reliability of the fuzzy Delphi method questionnaire were controlled by using purposive sampling and reaching theoretical saturation, sensitivity to selected indicators and components, ideological thinking, continuous rereading and analysis of responses, and reviewing literature and empirical research foundations.

The statistical population of the research in the meta-synthesis section included articles published in various scientific databases in English, including Google Scholar, Springer, Science Direct, Scopus, Wiley, and Emerald Insight, and scientific databases in Persian, including: Noormags, magiran, and Sid. Also, the statistical population of the research in the fuzzy Delphi section included 20 experts from the academic scientific community and education specialists who had executive backgrounds at decision-making levels and were known as experts in reform. They were selected purposefully based on their expertise and familiarity with the research topic and responded to the questionnaire in two stages to indicate their level of agreement with the extracted. In

the next step, the final weight of the desired components was calculated based on the SWARA method, based on which, at first, the desired components were sorted by the experts according to the degree of importance, and the most important elements were ranked higher based on the definite average of the fuzzy Delphi method. Then the relative importance of each component compared to the previous component was expressed as a percentage. To find this value, the average of the standard $j-1$ is subtracted from the average of standard j, and the obtained result is divided by the average of $j-1$, and the calculated percentage values are the output of S_j values. In the next step, the K_j coefficient, which is a function of the relative importance of each component, is calculated through equation (6):

(6) $K_j = S_j + 1$

The initial weight of each component is also calculated through equation (7) and we consider the initial weight of the first component, which has the highest importance, to be 1.

(7) $Q_j = \frac{Q_{j-1}}{K_j}$

In the last step of the SWARA method, the final weight of the components, which is also considered the normalized weight, is obtained with the help of equation (8):

(8) $W_j = \frac{Q_j}{\sum Q_j}$

The statistical population of the SWARA method included experts in the field under study. In this method, specialists and experts are important in evaluating the calculated weights. 12 people were purposefully selected as a sample. Each expert determined the importance of each indicator based on their tacit knowledge, information, and experiences. The weight of each indicator was determined based on the average value of the group rankings obtained from the experts.

In the second stage, a quantitative strategy and a survey method helped test the research's conceptual model using a questionnaire and confirmatory factor analysis method. The statistical population of the study at this stage was all the male and female primary teachers of Tabriz city in the academic year 1402-1403, and the sample size was determined using Cochran's formula (P = 0/5, D = 0/5) 400 were determined. Due to geographical dispersion, using a cluster random sampling method, Tabriz city was first divided into 5 parts: North, South, East, West, and Center, and then one region was randomly selected from each part. Then, based on the stratified sampling method, the number of statistical samples for each region was determined, and finally, by considering the sample ratio for each region, the statistical sample of this study was selected and the questionnaire was distributed among them (table 2). The reliability coefficient and internal homogeneity of the questionnaire items were calculated using SPSS26 application and Cronbach's alpha coefficient. Also, the validity of the questionnaire was done with the AMOS 26 application and through confirmatory factor analysis, which is explained below in the fit indices of each of the concepts.

Table 2: Statistical sample by region (quantitative stage)

Region	Number of teachers	Statistical sample
1	322	54
3	697	116
4	309	52
12	408	68
15	664	110

Findings

Part 1 (Qualitative)

Question 1: What are the dimensions and components of teachers' professional learning network model?

To answer this question and identify the dimensions and components of teachers' professional learning network models, the meta-synthesis method, according to Sandolowski and Barroso's (2006) six-step method was used. The steps of implementing this method and the results obtained from it are explained below.

1. Determining the research question

At this Step, indicators (what, who, when, and how) were used to determine the research question. Based on this, the research questions were formulated as follows:

What: The purpose of this index is to explain the desired study, which in this research is "What is the model of teachers' professional learning networks?"

Who: It means the community under study, which means valid domestic and foreign scientific publications.

When: This index shows the time period of the studied studies, which is considered to be 2005-2024.

How: The meaning is the data collection method, which is the review of articles and research based on analyzing the intended themes.

2. Search for resources

In this step, after defining the topic, sample members, time, and method, the researchers searched for keywords related to the research topic in different scientific databases. Keywords searched in scientific databases include: Teachers' learning, teachers' professional learning, teachers' professional development, teachers' professional communities, teachers' learning communities, teachers' professional learning communities, teachers' network learning, teachers' learning networks, teachers' professional learning networks, teachers' professional networks, networking in education, teachers' learning groups, teachers' professional associations, teachers' training groups, teachers' teaching-research, teachers' professional cooperation, teachers' cooperation, networked learning communities.

3. Quality assessment

In this step of the research, the researchers evaluated the articles selected in the previous step based on the criteria of critical evaluation (CASP[1]). This program provides a standard mechanism for evaluating the quality of qualitative studies included in meta-synthesis and is considered one of the most complete tools with ten evaluation criteria (Walsh & Downe, 2005). The documents were divided into 5 categories based on the rating scale of the researchers: excellent (41-50), very good (31-40), good (21-30), average (11-20), and weak (0-10). The results of the critical evaluation of the selected research based on the CASP index show that 12 articles were in the excellent category, 19 articles were in the very good category and 4 articles were in the good category, which totaled 35. The articles were selected for review in the meta-synthesis stage. Finally, Figure (2) shows the process of selecting and screening articles based on the objectives and questions of the present study and with the help of the PRISMA[2] algorithm.

[1] . Critical Appraisal Skills Program

[2] . Preferred Reporting Items for Systematic Reviews and Meta-Analyses

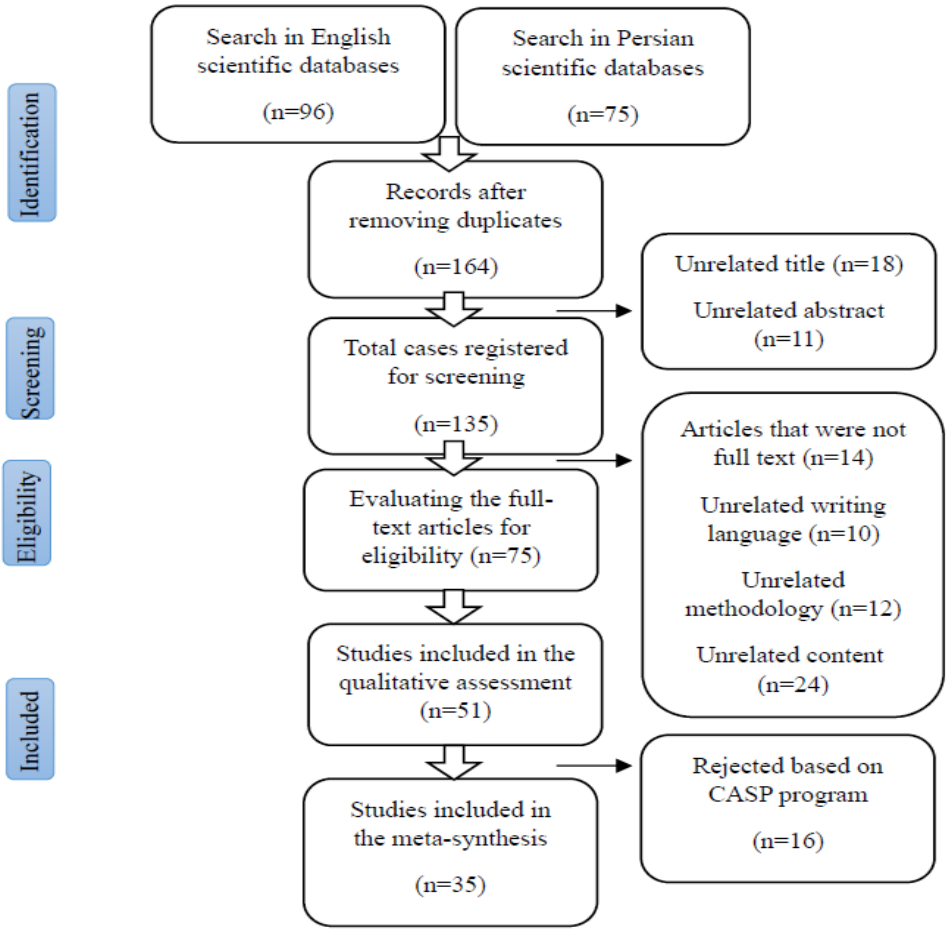

Figure 2. PRISMA flow diagram of study selection and inclusion process (Luo et al, 2023)

1. Analysis

At this step, the selected articles of the previous stage were analyzed with the help of MAXQDA20 application, and the basic information of the articles including: (research title, authors' names, year of publication, country, research method, and primary codes) were extracted. After the basic information of the articles was identified, data was identified and extracted, and all the extracted factors were considered as codes (basic themes). Then each of these codes was categorized in a similar concept and the concepts (organizing topics) of the research were formed.

2. Combination of findings

At this step, the findings of the previous steps are combined with the help of metaphors, which are concise, innovative, and more valid in scope. The phrases are edited and summarized in a short format to summarize the findings. In general, in the current research, 308 codes were taken from the studied sources, and these codes were placed in 15 concepts and 3 main categories. The information related to this step is shown in Figure (3).

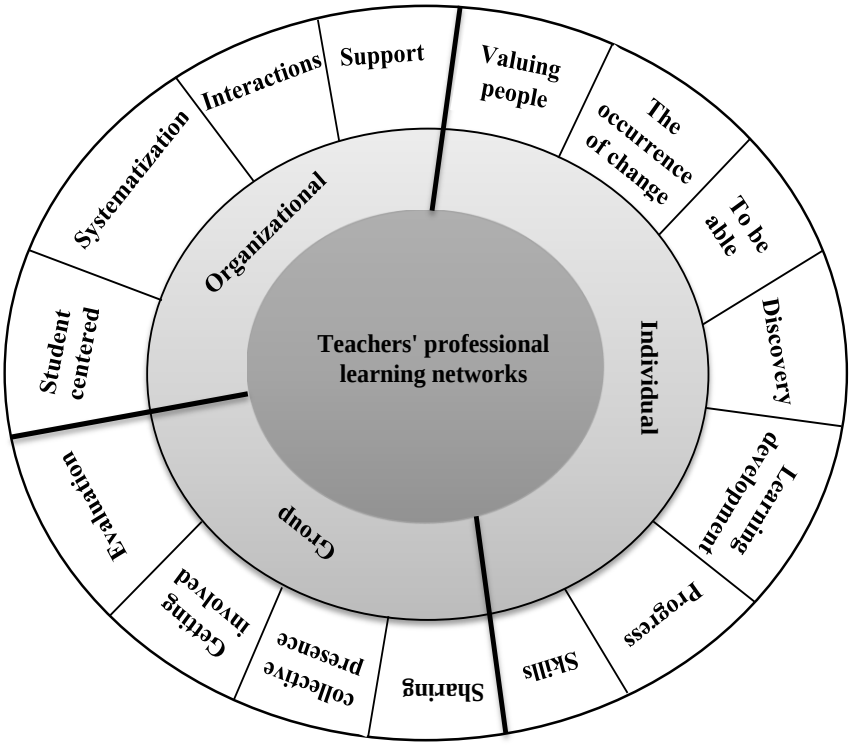

Figure 3. Conceptual model of teachers' professional learning networks extracted from meta-synthesis findings

After specifying the conceptual model of the research, the frequency of each of the three categories of individual, group, and organizational is presented in Table (3).

Table (3): Dimensions and components of teachers' professional learning networks

Numbers	Category	Concepts	Frequency of codes	Total frequency	Source number
1	Individual	Valuing people	22	501	34,5,351,2,8,31,13,24,32,33
		The occurrence of change	104		20,25,4,5,9,11,15,18,28,8,12,13,17,1,9,26,29,30,1,8,24,3,4,31,7,16,14,3,2,21
		To be able	47		25,5,1,2,19,21,20,8,15,28,7,29,34,9,26
		Discovery	68		2,4,5,7,13,26,8,15,20,24,27,28,29,33,35,1,6,23,25,32,11,21,22,31,34
		Learning development	48		1,2,3,5,7,8,9,11,12,13,14,16,18,26,34,31,28,27,6,15,6,20,21,19,25,35
		Progress	155		5,6,8,10,16,24,26,28,33,4,9,11,14,29,34,31,1,4,7,13,15,18,22,2,3,12,23,21,20,32,27,7,25,19
		Skills	57		4,5,7,8,9,10,11,13,14,15,16,18,21,22,24,28,29,30,26,20,33,34
2		Sharing	263		22,23,24,25,26,27,28,31,32,33,34,35,13,14,15,2

	Group			401	0,1,2,3,4,5,6,7,8,9,10,11,16,18,19,29,12,17,21,30
		collective presence	65		1,2,6,7,16,21,24,33,3,8,4,5,22,14,28,1,5,34,32,29,27,26,18,19,31,20,35,30
		Getting involved	35		24,33,3,5,6,22,18,23,4,12,17,19,28,1,7,13,19,29,32,34,26
		Evaluation	38		4,5,7,9,10,13,14,21,26,27,28,31,33
3	Organizational	Student centered	41	324	33,30,28,22,21,15,13,29,34,7,17,19,1,8,11,12,16,29
		Systematization	28		35,25,2,20,3,6,7,8,19,20,12,17,27,30
		Interactions	198		1,4,5,12,16,17,18,19,20,24,25,26,29,32,33,34,3,8,9,21,6,7,9,10,13,14,15,27,28,31,22,11,35
		Support	57		19,33,5,6,9,10,13,14,25,28,30,31,1,4,17,18,21,22,35,34,32,29,27,24,12

1. Data validation

In conducting meta-synthesis research, researchers should always think of ways to improve the validity of their research during the implementation of the study. Throughout the steps of conducting this research, we have tried to go through the stages of the research carefully by providing the necessary explanations and using appropriate tools. Sandelowski & Barroso (2006) introduce four types of validation for conducting meta-synthesis studies, which include:

-Descriptive validation: Descriptive validity refers to the realness of the data. This means that in meta-synthesis research, all relevant research reports should be accurately identified and the information in each report should be described.

-**Interpretive validation:** Refers to the full presentation of researchers' opinions of the report. In other words, it is a type of narrative that is focused on the explanations related to member review or audience credibility.

-Theoretical validation: The methods used by the researcher in order to integrate and interpret the findings are called theoretical validity. Since the primary data in meta-synthesis studies include the findings of various study reports, theoretical validity refers to the validity of researchers' interpretations.

-**Practical validation:** It refers to the meaning of practicality, usefulness, ability to transfer knowledge, and appropriateness of meta-synthesis methodology. Based on the specified framework, validation and quality control of the findings were carried out according to the mechanisms in Table (4):

Table (4): Methods of optimizing the validity of qualitative meta-synthesis studies

Procedures	Validation type			
	Practical	Theoretical	Interpretive	Descriptive
Weekly meetings of the research group to discuss the search results and modify the search strategies				*
Independent evaluation of each report by at least two reviewers			*	*
Consultation with a competent librarian				*
Documentation of all processes, procedures, changes in the work process, and results	*	*	*	*
Weekly meetings of the research team to discuss the evaluation results and decide on the evaluation strategies of the studies			*	*
Consultation with higher education professionals	*			
Consultation with an expert in meta-synthesis research in the field of examining theoretical fields		*		
Weekly meetings of the research team to establish the agreed areas and negotiate them until a consensus		*	*	*

In this research, all the mentioned steps (Sandelowski & Barroso, 2006) were used to improve credibility. Accordingly, this research has four types of validity: descriptive, interpretive, theoretical, and practical.

Fuzzy Delphi method:

The Delphi phase method, whose steps are explained below, was used to screen and select the components identified in the meta-synthesis stage.

First stage survey

At this stage, a questionnaire containing 15 items was given to the experts. They were asked to express their opinion about each criterion in the form of Linguistic expressions included in the questionnaire. The numbers obtained from this stage are converted into fuzzy numbers based on the spectrum mentioned in Table (1) and then based on equations 2 to 4, their average is determined and finally, based on equation number 5, the fuzzy averages are converted to definite numbers. They become the results of this stage are listed in Table (5).

Table (5): Results of first stage survey

Category	Code	Concepts	Importance					Triangular fuzzy average	De-fuzzification
			(VU)	(U)	(MI)	(I)	(VI)		
Individual	IN1	Valuing people	0	0	1	2	17	(0/7,0/95,0/988)	0/709
	IN2	The occurrence of change	0	1	0	2	17	(0/688,0/938,0/975)	0/697
	IN3	To be able	0	2	1	2	15	(0/625,0/875,0/938)	0/641
	IN4	Discovery	1	2	1	2	14	(0/588,0/825,0/9)	0/606
	IN5	Learning development	0	1	3	2	14	(0/613,0/863,0/938)	0/631
	IN6	Progress	0	0	2	1	17	(0/688,0/938,0/975)	0/697
	IN7	Skills	1	1	1	2	15	(0/625,0/863,0/925)	0/641
Group	GR1	Sharing	1	1	0	3	15	(0/638,0/875,0/938)	0/653
	GR2	collective presence	1	0	1	1	17	(0/675,0/913,0/95)	0/684
	GR3	Getting involved	1	1	1	1	16	(0/638,0/875,0/925)	0/650
	GR4	Evaluation	1	1	3	2	13	(0/575,0/813,0/9)	0/597

Organizational	OR1	Student centered	2	1	2	1	14	(0/575,0/813,0/875)	0/594
	OR2	Systematization	1	1	2	3	13	(0/588,0/825,0/913)	0/609
	OR3	Interactions	0	0	2	2	16	(0/613,0/925,0/975)	0/688
	OR4	Support	1	1	2	1	15	(0/613,0/85,0/913)	0/628

Second stage survey

In this stage, the questionnaire of the first phase of the fuzzy Delphi and the indicators that the experts proposed were designed into a new questionnaire. Using the previous opinions of the people and the final average of the first stage, it was again sent to the group members. The results of this stage are shown in table (6).

Table (6): Results of second stage survey

Concepts	Importance					Triangular fuzzy average (step2)	De-fuzzification (step1)	De-fuzzification (step2)	De-fuzzification difference
	(VU)	(U)	(MI)	(I)	(VI)				
Valuing people	0	0	0	2	18	(0/725,0/975,1)	0/731	0/709	0/022
The occurrence of change	0	1	0	1	18	(0/7,0/95,0/975)	0/706	0/697	0/009
To be able	2	1	1	1	15	(0/6,0/825,0/888)	0/616	0/641	0/025
Discovery	1	1	0	2	16	(0/65,0/888,0/938)	0/663	0/606	0/057
Learning development	1	1	2	2	14	(0/6,0/838,0/913)	0/619	0/631	0/012
Progress	1	0	0	3	16	(0/675,0/913,0/963)	0/688	0/697	0/009
Skills	2	0	1	1	16	(0/638,0/863,0/963)	0/650	0/641	0/009
Sharing	1	2	2	2	13	(0/563,0/8,0/888)	0/584	0/653	0/069
Collective presence	2	0	0	1	17	(0/888,0/925,0/663)	0/672	0/684	0/012
Getting involved	1	2	0	2	15	(0/613,0/838,0/9)	0/628	0/650	0/022
Evaluation	2	2	1	2	13	(0/55,0/775,0/863)	0/572	0/597	0/025
Student centered	0	2	3	1	14	(0/588,0/838,0/913)	0/606	0/594	0/013
Systematization	1	2	2	1	14	(0/575,0/813,0/888)	0/594	0/609	0/015
Interactions	0	1	1	3	15	(0/65,0/9,0/963)	0/666	0/688	0/022
Support	2	2	0	1	15	(0/588,0/813,0/875)	0/603	0/628	0/025

Table (6) shows the triangular fuzzy average, the second stage de-fuzzification, and the difference between the first and second stage de-fuzzification. If the difference between the two stages of the survey is less than 0/1, the survey process is stopped, which means that we have reached a consensus. If the average difference of all indicators is less than 0/1, the Delphi phase process is stopped, which means that the experts have almost the same view on the components and dimensions identified in the research.

Question 2: How are the dimensions and components of teachers' professional learning networks prioritized?

The SWARA method was used to prioritize the dimensions and components identified in the meta-synthesis stage. The findings are explained below.

SWARA method

At this stage, the concepts of teachers' professional learning networks were sorted from high to low based on

the definite average of the fuzzy Delphi method, and their final weight was calculated based on the number of equations (6) to (8). This method is beneficial when the number of components is large. The output of the fuzzy Delphi method, which is the definite weights of the elements, was used as input in the SWARA method. The results of this stage are given in table number (7).

Table (7): The final weight of the concepts identified in the research

Priority	Concepts	Definite average	S_j	K_j	Q_j	W_j
1	Valuing people	0/731	1	1	1	0/076
2	The occurrence of change	0/706	3/541%	1/035	0/966	0/073
3	Progress	0/688	2/616%	1/026	0/941	0/071
4	collective presence	0/672	2/380%	1/023	0/919	0/070
5	Interactions	0/666	0/900%	1/009	0/910	0/069
6	Discovery	0/663	0/452%	1/004	0/906	0/069
7	Skills	0/650	2%	1/02	0/888	0/067
8	Getting involved	0/628	3/503%	1/035	0/857	0/065
9	Learning development	0/619	1/453%	1/014	0/845	0/064
10	To be able	0/616	0/487%	1/004	0/841	0/064
11	Student centered	0/606	1/650%	1/016	0/827	0/063
12	Support	0/603	0/497%	1/004	0/823	0/062
13	Systematization	0/594	1/515%	1/015	0/810	0/061
14	Sharing	0/584	1/712%	1/017	0/796	0/060
15	Evaluation	0/572	2/097%	1/020	0/780	0/059

According to the information in table number (7), valuing people was the first priority among the identified concepts. The occurrence of change, progress, and collective presence were also among the next priorities.

Next, to prioritize the main components, the average concepts of each component were calculated and sorted in descending order, and using the SWARA method, the weight of the main components was calculated, which is given in Table (8).

Table (8): The final weight of the categories identified in the research

Priority	Category	Definite average	S_j	K_j	Q_j	W_j
1	Individual	0/667	1	1	1	0/351
2	Organizational	0/617	8/103%	1/081	0/925	0/325
3	Group	0/614	0/488%	1/004	0/921	0/323

According to the information in Table (8), the individual category had the first priority among the identified categories. The organizational and group categories were also the next priorities.

Part 2 (Quantitative)

Question 3: What is the degree of appropriateness of the provided model?

To answer this question, First, the basic assumptions of structural equation modeling should be examined. These assumptions include identification and removal of outlier data, univariate and multivariate normality, reasonable sample size, and sampling adequacy.

Identifying and removing outlier data (Mahalanobis index)

The Mahalanobis index was used to check multivariate outlier data, which is calculated with the help of AMOS application and the significance level is reported for that. If the Mahalanobis index is significant for a sample, it

means that there is a significant difference between the responses of this sample and other respondents. If p-value1 and p-value2 are less than 0/01 simultaneously, that case is known as outlier data, which is removed or modified from the data file before performing structural equations. The result of the Mahalanobis index is reported in the table below.

Table (9): Calculation of Mahalanobis index to identify outlier data

Observation number	Mahalanobis d-squared	p1	p2	Observation number	Mahalanobis d-squared	p1	p2
4	77/409	/000	/000	167	20/640	/149	/503
406	73/134	/000	/000	40	20/640	/149	/449
405	64/631	/000	/000	158	20/378	/158	/598
1	44/457	/000	/000	34	20/365	/158	/554
5	43/764	/000	/000	346	20/356	/159	/507
408	41/459	/000	/000	267	20/272	/162	/520
404	40/494	/000	/000	198	20/186	/165	/536
407	38/523	/001	/000	63	20/104	/168	/549
30	32/148	/006	/001	23	20/104	/168	/496
24	31/843	/007	/001	33	20/096	/168	/450
121	31/200	/008	/001	64	20/002	/172	/474
31	30/921	/009	/000	399	20/001	/172	/423
126	30/622	/010	/000	400	19/977	/173	/392
28	30/236	/011	/000	315	19/783	/180	/500
27	29/399	/014	/001	133	19/777	/181	/454
96	27/669	/024	/037	153	19/730	/183	/442
200	26/928	/029	/096	154	19/705	/184	/413
124	26/532	/033	/128	122	19/456	/194	/574
195	26/181	/036	/160	89	19/426	/195	/550
57	25/611	/042	/282	258	19/394	/196	/527
393	25/477	/044	/258	159	19/289	/201	/568
201	25/337	/046	/240	131	19/286	/201	/522
29	25/279	/046	/195	100	19/185	/205	/560
2	24/662	/055	/386	92	19/122	/208	/567
59	24/632	/055	/322	48	18/774	/224	/794
398	24/312	/060	/404	295	18/759	/225	/769
120	24/019	/065	/482	102	18/629	/231	/819
22	23/992	/065	/419	309	18/619	/232	/792
402	21/770	/114	/430	32	18/592	/233	/775
39	21/744	/115	/388	51	18/483	/238	/812
19	21/742	/115	/333	397	18/435	/240	/810
326	21/556	/120	/400	256	18/361	/244	/825
83	21/543	/120	/352	328	18/209	/252	/880
119	21/450	/123	/358	138	18/208	/252	/855
338	21/194	/131	/483	137	18/192	/253	/837
118	21/090	/134	/503	8	18/131	/256	/843
336	20/935	/139	/560	87	18/130	/256	/815
123	20/761	/145	/633	85	18/083	/258	/814
310	20/718	/146	/610	130	18/040	/261	/810
197	20/712	/146	/559	313	18/017	/262	/794
62	20/672	/148	/535				

Checking the normality of the variables (Shapiro-Wilk Test)

To analyze the data and choose the type of relevant tests, we must first check the normality of the variables If the variables are normal, both parametric and nonparametric tests can be used. However, if the variables are abnormal, only nonparametric tests can be used. The test that is used to check the normality of the variables is the Shapiro-Wilk test. Therefore, the following two hypotheses are proposed:

H_0: The variable has a normal distribution

$H_{1:}$ The variable does not have a normal distribution

Table (10): The results of checking the normality of research variables

Variable	Statistics	Skew	Kurtosis	Status
Individual	0/10	-0/315	-0/204	Normal
Group	0/14	-0/216	-0/413	Normal
Organizational	0/06	0/192	-1/301	Normal

The skewness and kurtosis indices of the variables are placed between (-2,2). Therefore, the distribution of variables is very similar to the normal distribution. So, the data can be considered normal based on the skewness and kurtosis indices and the Shapiro-Wilk test.

Multivariate normality (Mardia coefficient)

Reporting indicators of univariate normality is important because if univariate normality is violated, multivariate normality will also be violated. And univariate normality alone is not enough and it is necessary to check multivariate normality as well. If multivariate normality is not established, the Bootstrap method is used to estimate structural model parameters.

Table (11): Checking multivariate normality

Mardia coefficient (multivariate normality)	Z	Result
4/803	1.758	Multivariate normality is established

The value of the Z statistic is less than (1/96), which confirms the null hypothesis of multivariate normality at the 95% confidence level. The hypothesis that the data distribution is non-normal is rejected.

Reasonable sample size and sampling adequacy (KMO[1] test)

According to James Stevens, it is desirable to consider 15 items for each predictor variable. Based on this, Loehlin concludes that for models with two or four factors, the researcher should collect at least 100 samples. Smaller samples will not achieve convergence and create standard errors, so it is better to get more data. The number of samples in this research was equal to 450 people, and sampling adequacy can be ensured (Hooman, 2021). The KMO test is used to calculate the statistical power and confirm the adequacy of the sample size before performing the factor analysis. This test determines whether the variance of the research variables is affected by the common variance of some hidden and fundamental factors or not.

Table (12): KMO test results

Variable	KMO	Result
Individual	0/777	Statistical power and sample adequacy are confirmed
Group	0/856	Statistical power and sample adequacy are confirmed
Organizational	0/818	Statistical power and sample adequacy are confirmed

According to the results of the table (12), the value of KMO for all scales is greater than 0/7. Therefore, the sample size is good enough to perform a confirmatory factor analysis.

Evaluation of measurement models

In this research, separate dimensions and items were used in the questionnaire to measure the "individual", "group" and "organizational" components. The AMOS26 application confirmed the fit of each measurement model with the confirmatory factor analysis method. The measurement models are shown in the standard operating mode. If the factor loadings are more than 0/5, the item explains the variable well. The significance level of factor loads is also shown in the form of a table with P-VALUE and CR indicators.

[1] . Kaiser-Mayer-Olkin

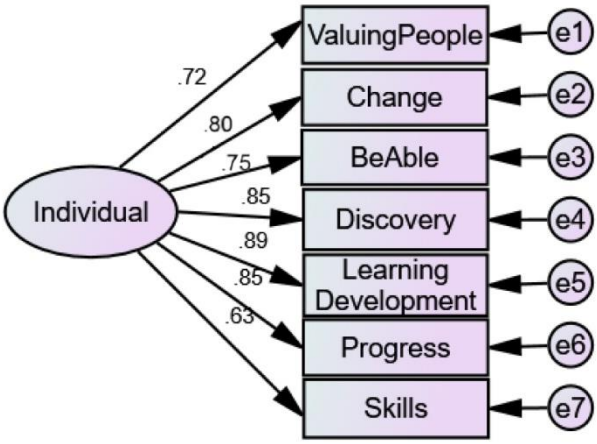

Figure (4). Individual component measurement model

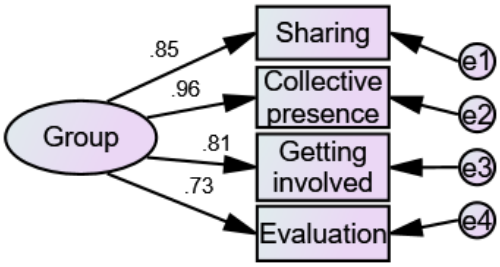

Figure (5). Group component measurement model

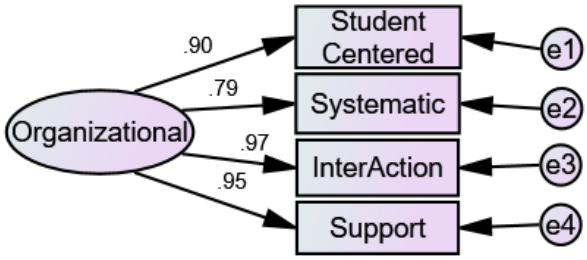

Figure (6). Organizational component measurement model

As seen in the measurement models, the factor loading of most items is more than 0/7, in other words, more than 49% $(0/7^2 = 0/49)$ of the changes in each item are explained by the underlying variable. The results of the fit indices of the measurement models are mentioned in the table (13).

Table (13): Fit indices of measurement models

index	optimal	Individual	Group	Organizational
X2/df	≤ 3	1/57	2/712	2/823
RMR	Close to 0	0/091	0/003	0/017
GFI	$\geq 0/9$	0/925	0/951	0/963
AGFI	$\geq 0/9$	0/930	0/940	0/971
NFI	$\geq 0/9$	0/920	0/930	0/970
RFI	$\geq 0/9$	0/911	0/908	0/907
IFI	$\geq 0/9$	0/912	0/984	0/980
TLI	$\geq 0/9$	0/950	0/914	0/919
CFI	$\geq 0/9$	0/950	0/974	0/979
PRATIO	$\geq 0/5$	0/813	0/857	0/667
PNFI	$\geq 0/5$	0/816	0/622	0/581
PCFI	$\geq 0/5$	0/620	0/624	0/586
RMSEA	$< 0/08$	0/053	0/037	0/021

The results of table (13) show that the fit indices of all measurement models are at the optimal level, so the measurement models are approved.

Significance of measurement models

In AMOS application, the significance level of factor loads is displayed with P-VALUE and CRITICAL RATIO (CR) indicators, the results of which are reported in Table (14).

Table (14): Significance of measurement models

Dimensions	Items	factor load	CR	P-VALUE
Individual	Valuing people	0/720	12/322	***
	The occurrence of change	0/801	13/708	***
	To be able	0/753	12/886	***
	Discovery	0/845	13/878	***
	Learning development	0/891	14/359	***
	Progress	0/849	13/919	***
	Skills	0/634	10/412	***
Group	Sharing	0/854	14/024	***
	Collective presence	0/963	15/814	***
	Getting involved	0/808	13/269	***
	Evaluation	0/727	11/939	***
Organizational	Student centered	0/897	14/730	***
	Systematization	0/794	13/039	***
	Interactions	0/972	15/962	***
	Support	0/952	15/634	***

***: The factor loading is significant at the 99% confidence level.

The findings of Table (14) show that factor loadings are greater than 0/7 in each scale and the critical ratio is

greater than 2/58, so the significance of factor loadings is confirmed at the 99% confidence level.

The fit of the research's structural model was also examined through the Amos application, the results of which are explained below.

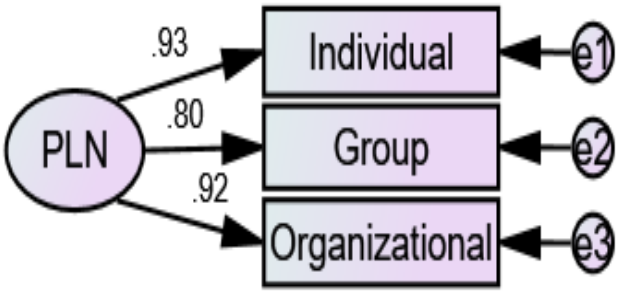

Figure (7). fitted structural model (standardized estimate)

To determine the fit of the structural model, fit indices were calculated and the results are shown in table (14)

Table (15): structural model fit indices

index	optimal	Reported value
X2/df	≤ 3	2/630
RMR	Close to 0	0/041
GFI	$\geq 0/9$	0/911
AGFI	$\geq 0/9$	0/903
NFI	$\geq 0/9$	0/910
RFI	$\geq 0/9$	0/900
IFI	$\geq 0/9$	0/914
TLI	$\geq 0/9$	0/923
CFI	$\geq 0/9$	0/934
PRATIO	$\geq 0/5$	0/872
PNFI	$\geq 0/5$	0/725
PCFI	$\geq 0/5$	0/708
RMSEA	$< 0/08$	0/061

The results of the indicators in Table (15) show that the research's structural model is well-fitted.

Checking the validity and reliability of the constructs

In the present study, the average variance extracted index (AVE) and composite reliability index (CR) were used to check the validity and reliability of the constructs. Researchers consider a value of 0.5 or higher suitable for the AVE index, and values higher than this value indicate the appropriate validity of the constructs under investigation. Also, if the value of CR for constructs is greater than 0.6, they show acceptable reliability, and the closer this value is to one, the higher the reliability of that construct—results These indicators are mentioned in the table (16).

Table (16): Validity and reliability index values of the research constructs

Main dimension	AVE	CR
Individual	0/629	0/941
Group	0/601	0/926
Organizational	0/580	0/960

For each Construct, two indices, Average Variance Extracted (AVE) and Composite Reliability (CR), are calculated to measure the validity and reliability of the constructs, respectively. The AVE index indicates what percentage of the variance of the construct under study was influenced by the indicators of that construct. The AVE index is used to measure construct validity and is also referred to as convergent validity. Researchers have determined a value of 0/5 or higher to be appropriate for this index. The composite reliability (CR) method was also used to determine the reliability of the constructs. If the CR value for the constructs is greater than 0/6, they show acceptable reliability, and the closer this value is to 1, the greater the reliability of that construct. The results of Table (16) show that the AVE index for all constructs is more than 0/5, and the CR index is more than 0/6. Therefore, each of the model's constructs has good convergent validity and composite reliability for measuring research variables.

Finally, based on the examination of the theoretical foundations and the analysis of the findings of the current research, the schematic model resulting from the qualitative and quantitative stages is shown in figure (7) as the final output of the research.

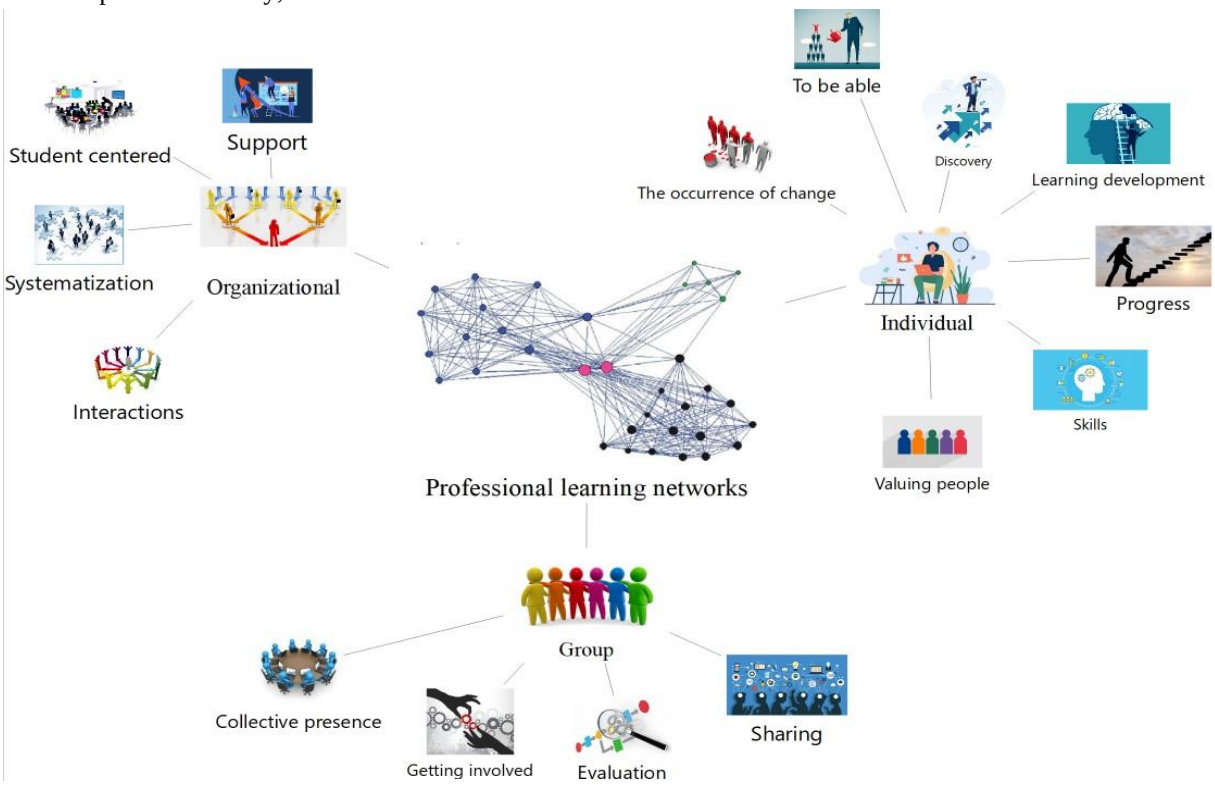

Figure (8). The schematic output of MAXQDA for the research conceptual model

Discussion and Conclusion

The issue of "how teachers and educational leaders learn in professional learning networks" needs attention and investigation (Pedersen et al, 2024, p.1). The present study identified and validated the dimensions and components of the teachers' professional learning network model. The results showed that this model has three categories: individual, group, and organizational, each containing different concepts. The individual category included the concepts of valuing people, the occurrence of change, being able, discovery, learning development, progress, and skills. These findings can be compared with the research results (Oddone et al, 2019); (Azorín, 2018); (Gatz & Akiva, 2024); (Trust et al., 2016); (Schnellert & Butler, 2021) and (Rafai et al, 2020) agreed. By joining professional learning networks, teachers can have the most impact on the individual field and help to improve their professional knowledge through individual learning, which leads to successful attendance in classrooms and improved teaching-learning processes. On the other hand, teachers' self-efficacy improves through the growth of personal knowledge and personal development, and they reach an inner belief that makes them more capable of facing issues and problems. The most important effect that membership in professional learning networks has had on teachers is the improvement of their teaching methods, which leads to the improvement of the educational situation, especially in schools in deprived areas, which is in line with the results of the research (Brown & Flood, 2020). Teachers' abilities are another concept that expands through joining professional learning networks. Responsiveness, awareness, initiative, morale, efficiency, productivity, credibility, etc., are all the result of empowering teachers through networks, which ultimately leads to improving the quality of education. Having professional, human, social, and decision-making capital of members of schools and educational organizations is one of the advantages of joining networks, and this explanation is somewhat in line with the research results (Salehi et al, 2020). The expansion of networks among people creates innovation and creativity, and discovering new approaches and educational skills helps them to develop new methods and acquire new and up-to-date subject knowledge. Teachers who are motivated to participate in networks are lifelong learners who always seek to develop their learning, and in this way, social interactions between learners create conditions and opportunities to enrich and strengthen learning. Teachers participating in networking activities face a wide range of opportunities for individual professional growth and development. Especially the online social networks that have been made available formally and informally as a tool for their professional learning, this is the space where teachers improve their knowledge, access diverse perspectives and ideas, and interact with Coaches, with different levels of expertise and experience, can be considered as a tool for their individual development. Expanding skills is another concept that teachers benefit from by participating in professional learning networks. Familiarity with digital technologies, teaching methods, educational philosophies, educational resources, curriculum design, planning, etc., helps teachers to have a better understanding of educational strategies.

Also, based on the results, the group category included the concepts of sharing, collective presence, involvement, and evaluation. These findings can be compared with the research results (Davis, 2015); (Trust, 2017); (Chapman, 2008); (Judy et al, 2018); (Van den Beemt et al, 2018); (Vangrieken et al, 2015); (Rafai et al., 2020); (Anderson et al, 2019) and (Brown et al, 2021) found it consistent. Networks are beneficial for knowledge sharing, collaboration, and performance development across schools. Learners exchange their resources and experiences with other people and share their unique goals and plans, expressing their ideas, concerns, attitudes, and values, and getting new ways and insights. Instead of individualism and isolation, they have access to a set of common ideas and ideals, and communicating with others and focusing on a common overall goal helps educators to progress. Teachers can find resources based on their topic(s) of interest, learn about new approaches, and find answers to their questions in a short amount of time, and are allowed to share their expertise publicly with local and global peers. Share and have access to each other's personal knowledge and exchange information sources with each other. The collective presence of teachers in various group activities has strengthened the social capital in schools and can be a powerful lever for change. Social capital relies on common norms, values, trust, and mutual interests that exist in social groups. Collaborative functions in networks are associated with creating a sense of collectivism and allow teachers to discuss concepts, skills, and problems in their work. Similarly,

social capital is a source of useful information and resources that can lead to the improvement of human capital. Online networking activities provide a platform for teachers where people can cross-examine the activities of their colleagues and provide support, advice, and feedback to their peers around the world about their personal experiences. To receive recommendations from teaching that this result is in line with the research findings (Gandomi & Sajjadi, 2016).

In addition, the results showed that the organizational category included the concepts of Student-centered, Systematization, interactions, and support. These findings can be compared with the research results (Trust et al, 2016); (Brown et al., 2021); (Rincón-Gallardo & Fullan, 2016); (Brown, 2023); (Gatz & Akiva, 2024); (Tour, 2017) and (Oddone et al, 2019) agreed. The ultimate goal of creating professional learning networks among teachers is to improve students' results. The main core of education and training activities all over the world is students, and all policies and planning are organized in the direction of learning in this group. Elementary school is the most important stage of education in all educational systems. This period changes the child's life in a real sense, and the child's talents should be developed. Therefore, the primary period plays an important role in fostering children's creativity and their success in adulthood. Undoubtedly, the teacher, especially in primary education, is one of the most important factors of the educational environment, which organizes and equips the educational environment by knowing each student and their facilities and deficiencies, and is the most essential factor for creating favorable conditions. To achieve the educational goals. Networks can be considered as systems that have a flat structure and are a combination of people, spaces, and tools that follow coordinated actions through interactions and in a favorable environment that is filled with trust and emotional support. It is connected, and they communicate through technology and social media, and the beneficiaries of the networks participate in decision-making by facilitating links, and parents and families in the future of learning. Their children become partners in the space provided for the expansion of collective knowledge, and it is possible to take advantage of the potential capabilities of experts from other organizations and university researchers in solving organizational problems.

One of the limitations of the current research was the lack of sufficient empirical background in domestic studies on the formation of professional learning networks, especially among primary teachers, and the researchers found a handful of related domestic articles at the stage of examined meta-synthesis, and hence it is suggested to future researchers to focus more on the topic of networking among teachers. Identifying the factors influencing the formation of professional learning networks among teachers in our country can solve their professional development problems. Most importantly, examining the role of school principals' leadership styles on the formation of networks can also be useful, and it is suggested that researchers use other qualitative methods, including interviews, to investigate the nature of networks. Identifying the dimensions and components of professional learning networks among university professors should also be considered..

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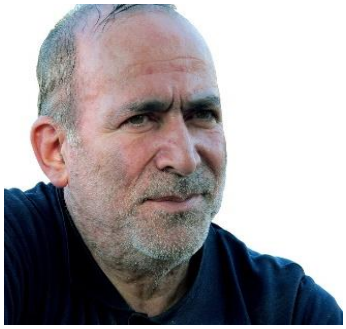

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