Development and validation of a scale for measuring the PCK of primary education student- teachers

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Abstract

Pedagogical Content Knowledge (PCK) has a very important impact on designing and implementing the teachers' teaching at schools. Therefore, in the current situation, development and efficiency of this knowledge, its relationship with the quality of education and its impact on the learning processes should be carefully examined. The purpose of this research was developing a scale for measuring the PCK of primary education student-teachers and determining its validity. It was a descriptive study. The research population included all primary education student-teachers of Farhangiān University, from which ٢٠٣ students (١٢٠ females and ٨٣ males) were selected as the research sample. They filled out the online questionnaire. First, the components of the scale were extracted through reviewing the related literature. Then, in order to determine the correlation among the components and also determining the validity of the scale, Pearson correlation coefficient and confirmatory factor analysis were used. Also, Chronbach's alpha was used to examine its reliability (α = ٠,٩٠). Findings showed that there was a positive and significant correlation among the components of the scale and the scale has an acceptable content validity. The construct validity of the scale was determined using exploratory factor analysis by principal components method. Finally, the scale was determined as having three main components of knowledge of curriculum, knowledge of learner and knowledge of teaching strategies. So, it could be concluded that the PCK scale has appropriate validity in the Iranian society and it could be used in the organizational situations and research related to the PCK.

Keywords: Testing, Validation, Pedagogical Content Knowledge (PCK), Primary Education Student-Teachers, Confirmatory Factor analysis

Introduction

To achieve the learning objectives in accordance with the national curriculum, teachers have an important role in shaping students' learning processes. Bransford et al. (٢٠٠٠) believe that teachers are the key to enhancing students' learning at schools and the main determinant of educational performance and students' learning outcomes (Quoted from Darling-Hammond, ٢٠٠٠; Schleicher, ٢٠١٦). Hence, teachers need a variety of professional resources for teaching. Research studies have shown that teachers' knowledge about different dimensions of education,

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learning, and learner has an important effect on their professional skill and qualification, effective teaching, and the quality of education (Baumert et al., ۲۰۱۰; Hill et al., ۲۰۰۸).

Teacher training centers are among the centers that play an essential role in shaping teaching knowledge, skills, and ethics. Thiessen (۲۰۰۰) emphasizes three main trends in teacher training programs: effective behavior, reflective activities, and professional knowledge. According to Thiessen, the final trend, professional knowledge, is the most important and promising trend for teacher training programs. Teaching as a knowledge is at the center of this trend and it includes subject knowledge and practical knowledge (reported from Verloop, ۲۰۰۱).

As a result, one of the important goals of teacher training in many countries of the world is to expand and grow the knowledge and qualifications of pre-service teachers (Cochran & Villegas, ۲۰۱٦; European Commission, ۲۰۱۳). Teachers' professional qualification could be defined as "what teachers need to do their job successfully throughout their career" (Biomeke et al., ۲۰۰۸). Experts have consensus on the multidimensional nature of teachers' professional qualification, including the cognitive aspects (professional knowledge) and the emotional-dynamic aspects (professional beliefs and motivational orientations) (Baumert & Kunter, ۲۰۱۳; Biomeke, ۲۰۱۷).

The significant role of pre-service teacher training programs in preparing qualified teachers is almost an undisputed issue in the teacher education literature (Smith, ۲۰۰٥). Through these programs, teachers take the first steps towards professionalism (Freeman & Johnson, ۱۹۹۸; Smith, ۲۰۰٥), gain more confidence in teaching well (Darling-Hammond, ۲۰۰۲), and expand the domain of their knowledge base (Akbari & Dadvand, ۲۰۱۱).

The fundamental changes that took place in the direction of teacher training programs during the last two decades of the twentieth century have more complicated the important task of teacher educators (Freeman, ۲۰۰۲). Before the mid-۱۹۷۰s, the product-process approach was used to educate teachers, supporting the idea that teachers should learn a set of predetermined behaviors with predictable learning outcomes to increase students' achievement (Freeman & Johnson, ۱۹۹۸). In such a context, the role of a teacher educator was to transfer personal and specialized knowledge to volunteers of teaching profession (Kumaravadivelu, ۲۰۱۲). However, when this traditional approach was replaced by a debate approach (Freeman, ۲۰۰۲), volunteers of teaching profession were referred to as "active and thoughtful decision-makers" (Borg, ۲۰۰۳) who used their previous experiences as a "student" to conceptualize teaching (Lortie, ۱۹۷٥), and this led to increasing the interest in teachers' beliefs (Pajares, ۱۹۹۲) and their recognition (Borg, ۲۰۰۳; Feryok, ۲۰۱۰). Therefore, teachers use their own knowledge when teaching in the classroom, and this knowledge has manifestations, rooted in the thematic demands while teaching. This knowledge is not something that could be easily answered by knowing how much one should specialize on that topic. Rather, it includes different dimensions of before, while, and after teaching qualifications (Mortazi & Gooya, ۲۰۱٤).

Researchers differentiate teacher knowledge into different areas (Baumert et al., ۲۰۱۰; Shulman, ۱۹۸۷; Tatto, ۲۰۱۲). The areas and categories of teacher knowledge that teachers should have were first introduced by Shulman (۱۹۸٦, ۱۹۸۷). Shulman (۱۹۸۷) identifies seven areas for teacher knowledge: ۱. content knowledge ۲. pedagogical general knowledge, including class management and organization ۳. curriculum knowledge, including materials

and programs ٤. learners' knowledge and their characteristics ٥. pedagogical areas' knowledge ٦. pedagogical purposes knowledge, objectives, values, and their philosophical and historical foundations ٧. PCK. However, most contemporary research focuses mainly on content knowledge, pedagogical knowledge, and PCK (Baumert & Kunter, ٢٠٠٦). Schulman considers PCK as the most powerful knowledge. From Schulman's point of view, PCK is a combination of educational knowledge and content knowledge relevant to the teacher. It helps him/her to streamline the teaching content as students' learn (Shulman ١٩٨٧). In fact, it could be said that the PCK is the interaction of subjects and effective teaching methods to help the students to learn the subjects. The teacher could choose specific strategies and information to decide how to teach subjects based on the PCK. Actually, the purpose of PCK is to integrate the general knowledge of education with real action that the teacher encounters while teaching a particular content (Eshter, ٢٠٠٨). To achieve this purpose, Schulman turned to professionalize the teaching job, and the claim that teaching is a profession was formed based on the belief that there is basic knowledge for teaching (Hashweh, ٢٠٠٥). He believes that PCK is necessary to understand issues, problems, organized topics to match and adapt to learners' different interests and abilities and to provide an instruction for education (Van et al., ٢٠٠٢).

Shulman (١٩٨٧) describes PCK as a combination of content knowledge and educational knowledge. Accordingly, it is expected that there is a correlation between this two knowledge. The results of the studies were in line with this expectation (reported from Krauss et al., ٢٠٠٨; Tepner & Dollny, ٢٠١٤). Based on what was mentioned above, Shulman (١٩٨٧) claimed that PCK is a distinct knowledge, although content knowledge and educational knowledge play a role in it. He also pointed out that PCK includes components such as learners' knowledge, teaching knowledge, educational materials' knowledge, and context. Over the past twenty-five years, this field has witnessed various developments in the conceptualization of PCK which has led to the formation of various theoretical models and metrics for this concept. In this regard, Tamir (١٩٨٨) made a more apparent distinction between general education knowledge and particular subject educational knowledge and, unlike other discussions on the components of PCK, emphasizes not only the thematic knowledge, but also the procedural nature of the PCK. According to him, PCK has been defined as the knowledge of how to change the subject to a specific subject to communicate with students. This knowledge includes understanding a specific and difficult subject, the concepts that students present to learn these concepts, and the teaching strategies appropriate to these particular educational conditions. He has also claimed that any type of knowledge is composed of the other categories of knowledge. In his study, Tamir (١٩٨٨) identified five components for the PCK: a) knowledge of orientation to teaching, b) knowledge on the students' understanding, c) knowledge of curriculum, d) knowledge of assessment, and e) knowledge of educational strategies.

In the same vein, Grossman (١٩٩٠) proposed a more accurate classification for the PCK based on Schulman's model of the components of teacher knowledge, which are:

a) Teachers' knowledge and beliefs about the objectives of teaching a subject to students at various levels, including their perceptions on the nature of the subject and important topics for students to learn about;

b) knowledge of students' prior knowledge, preconceptions, possible misconceptions, and alternative assumptions;

c) knowledge of the curriculum and materials, including knowing the intra and inter-subject relationships, and
d) knowledge of educational strategies and different representations.

Grossman believes that this knowledge includes knowledge of students' problems, misconceptions about subjects, knowledge of teaching methods and strategies, knowledge of the curriculum, and assessment knowledge to teach content knowledge effectively. Cochran also believes that the PCK consists of three knowledge, educational knowledge, subject knowledge, and background knowledge. He also believes that effective teaching is a combination of these three knowledge (Grossman, ١٩٩٠).

Magnusson et al. (١٩٩٩) also presented another model for PCK. They considered PCK as the teacher's understanding of how to help students understand a particular subject, including knowledge of organizing, representing the specific subjects tailored to the learners' different interests and abilities which are then offered for instruction. This model has accurately described the five components of PCK: ١) knowledge of orientation for education, ٢) knowledge of curriculum, ٣) knowledge about students' understanding of knowledge, ٤) knowledge of teaching strategy, and ٥) knowledge on the scientific assessment of literacy. The model of Magnusson et al. emphasizes the mutual interaction among the components of PCK, and this two-way interaction helps to form the components of PCK as a whole structure. However, the integrated view is not clearly seen throughout the model because there is only an interrelationship among the "orientation for science education" and the other four components, but not among the other four components. In fact, regarding the PCK, teachers should consider all of its components and make it as a comprehensive knowledge.

The first component of the above model is knowledge about education goals, which shows a subject from a horizontal and vertical perspective. Horizontal view refers to the general principle of teaching a particular subject, while vertical view refers to the purpose of teaching a subject at a particular level. This knowledge is considered the most important component of educational content knowledge (Magnusson et al., ١٩٩٩) because it directs the logical education and educational decision making. This knowledge guides the teachers to reconstruct the subject knowledge and demonstrate it understandably. This thematic knowledge filters teachers' reasoning through teaching, and this distinguishes teachers from content experts. In addition to a comprehensive understanding of subject knowledge, teachers must also understand and decide what to teach and how to teach.

The knowledge component of the curriculum is a separate area of basic knowledge for education. Magnusson et al. (١٩٩٩) consider curriculum knowledge as part of PCK, because they believe that curriculum knowledge is the knowledge that distinguishes the content specialist from the teacher. Another sub-category of curriculum knowledge includes knowledge of curricula and content related to teaching a particular subject. The knowledge component of the curriculum reflects the basic educational feature of PCK (Magnusson et al.,١٩٩٩). Curriculum knowledge demonstrate the learning objectives at the school context, so that it could help teachers, especially novice teachers to improve their teaching style. (Zahorik, ١٩٩١).

Learners' perceptual knowledge is the third component of the PCK model of Magnusson et al. (١٩٩٩) which means that teachers should know about learners to help them develop specific scientific knowledge. This knowledge has two subsections: The first is the knowledge

of learning needs which includes the knowledge and beliefs of teachers about the pre-requisite knowledge for learning specific knowledge, abilities, and skills that students need to learn specific concepts. Teachers also need to know how students differ in terms of growth, ability levels, and different learning styles. Teachers are expected to recognize learners' individual differences and provide different opportunities for learners with different needs. The second knowledge is in terms of students' problems which is another foundation and relates to teachers' knowledge of scientific concepts or topics that students find difficult to learn.

Knowledge on the evaluation of knowledge, i.e., the fourth component of the PCK model of Magnusson et al. (١٩٩٩) includes two dimensions: knowledge of the dimensions of learning science for evaluation and knowledge of evaluation methods. The first relates to aspects of students' learning knowledge that are important for assessing a particular subject, such as knowledge, application, and skills of the scientific process, and so on. The second relates to the knowledge of the appropriate method of assessing specific aspects of students' learning of a particular subject, such as the paper - pencil test, portfolios, practical laboratory test, and so on. Teachers are also expected to be aware of the strengths and weaknesses of an assessment method of a particular subject.

Knowledge of instructional strategies is the fifth and final component of Magnusson et al. (١٩٩٩) model of PCK. Knowledge of subject-specific strategies are strategies which are used to help students understand specific scientific concepts. This component consists of the following two dimensions: ١) knowledge of subject-specific strategies and ٢) knowledge of topic-specific strategies. The two dimensions are different in different contexts. subject-specific strategies mean specific programs for teaching science, and topic-specific strategies are specific programs for a subject or concept in science. Knowledge of topic-specific strategies includes general approaches which are used during the implementation of scientific guidelines such as learning cycle, guided research, concept change, and so on. Magnusson et al. (١٩٩٩) claimed that this knowledge is related to the orientation of science education. There are general approaches to science education that are consistent with the goals of specific orientations. This knowledge requires that teachers could describe and demonstrate the strategy and its steps effectively. Knowledge of topic-specific strategies is used to assist students in understanding specific features. They use knowledge of strategies to demonstrate specific concepts or principles to help students develop comprehension of analogies, models, images, and examples.

The two elements associated with PCK, i.e. subject representation knowledge, and students' pre-conceptual knowledge enable teachers to anticipate students' problems related to specific subjects and respond to them in appropriate ways. In addition, teachers could control the practical problems of their daily teaching flexibly. They should be able to analyze the value of different textbook examples about specific topics. They should also be able to follow up on different ideas that students come up with. Although teachers have general knowledge about students' problems, they often lack the skills to help students overcome them. To have a strong PCK, the teacher must have a good understanding of teaching content, and students' cultural background, background knowledge, and experiences. This knowledge varies considerably from teacher to teacher, and since each teacher is part of the context in which learning takes place, this knowledge remains a personal structure (Rowland et al., ٢٠٠٥). Although this knowledge is strengthened by daily teaching, however, experienced teachers also believe that

the need to develop specific teaching knowledge in teacher training programs is essential to teach effectively in the classroom. Some teachers even believe that daily teaching cannot help teachers identify students' preconceived notions and misconceptions about specific subjects. Given this limitation, it could be said that it is difficult for teachers to put this knowledge in practice unless teachers have a strong foundation in their training in teacher training centers, and it is necessary for teacher training students to learn educational specific knowledge as professional qualification in teacher training centers (Carlsen, ١٩٩٩).

Given that PCK is a powerful knowledge base for the training of skillful teachers, the status of research on PCK and its impact on the development of teacher education programs is examined. Different scales are designed to measure the PCK, each of which measures the components of PCK in different sciences. For example, a scale for measuring the knowledge of educational content (science, technology, engineering, mathematics) of pre-service teachers was designed by Aksu & Metin (٢٠١٤) in Turkey, which has five factors and it purpose has been to determine the PCK of pre-service teachers. Another scale for effective mathematics education (Guidelines for Effective Mathematics Teaching) was designed by Hudson & Skamp (٢٠٠٣). It was adapted from the primary school science education scale (guideline for effective basic science education, (Hudson & Peard, ٢٠٠٦) for mathematics. The only change is the replacement of “science” with “mathematics.” It should be noted that both scales are based on a five-factor model, i.e., personal characteristics, the required system, knowledge, modeling, and educational feedback.

Several other groups have also designed scales to assess the PCK of pre-service teachers of science and mathematics. Still, so far, a few tools have been published, and there is a lack of research on the scale for measuring the PCK of primary education student-teachers. Accordingly, the purpose of the present study was to construct a scale to measure the PCK of primary education student-teachers. Such a scale could show how much primary education student-teachers are familiar with pedagogical knowledge. The reason behind choosing the field of primary education was that the graduates of this field need to teach a variety of courses in the future. So, they must have a rich and developed PCK that will help them to teach all courses efficiently and successfully. Such a scale contributes to the self-awareness of primary school pre-service teachers by identifying perceptions related to PCK. It could also be used as a tool to support the growth of pre-service teachers, as it could be useful in identifying the components of PCK that pre-service teachers find themselves weak in those areas. Considering that the present study aims to investigate the psychometric indicators of the PCK questionnaire in primary education student-teachers, it seeks to answer the question of whether the factors of this questionnaire have acceptable psychometric indicators (validity and reliability) and construct validity?

Research Methodology

Given that this study aimed to construct and validate the questionnaire of PCK, the present study is descriptive. First, the literature of the teachers' PCK was studied to develop this scale. Based on the existing models, an attempt was made to use a comprehensive model as a basis. Accordingly, the Bukova-Güzel et al. (٢٠١٣) model was used to develop the scale, which could be seen in what follows.

Table ١. PCK framework

Knowledge of teaching, strategies and multiple presentations	Knowledge of Learner	knowledge of curriculum
Using appropriate activities in instruction	Having knowledge about students' prior knowledge	Being aware of the elements of the mathematics curriculum (their conception, purpose, etc.)
Using real-life examples and metaphors in instruction	Having knowledge of possible difficulties students may experience during learning	Being aware of the variety of instructural tools known in the mathematics curriculum and how to use them
Utilizing different strategies in presentations	Having knowledge of possible student misconceptions	Being aware of the instruments to assess student learning and how to use them
Making use of different presentations in instruction (graphics, tables, formulas, etc.)	Having knowledge of the difficulties and problems of students	Having both vertical and horizontal program knowledge of a topic

In the model of these researchers, PCK has three main categories, each includes specific elements. Based on the definitions, the identified elements, and available tools, ٤٢ items were developed of which ١٤ items were allocated to the component of knowledge of teaching strategies, ١٤ items to the knowledge of learner, and ١٤ items to the knowledge of curriculum. In the first step, these ٤٢ items were presented to the three experts with PhD in educational psychology to check their suitability and validity. The experts removed ٧ items due to the content overlap with the other items and the slight relation with the definition. In the next step, the remaining ٣٥ items were presented to ٣٠ students of primary education at Farhangiān University to determine the accuracy and significance of the items. Based on the results, ٦ items were removed, and ٢٩ items remained. These items were answered in a ٥-point Likert scale. The research population included all student-teachers of primary education in Farhangiān Universities. Due to the pandemic condition of Covid-١٩ and the closure of face-to-face training in Farhangiān Universities, and the impossibility of random sampling, an online questionnaire was designed using the Google Forms program. Data was collected with the cooperation and assistance of some Farhangiān University lecturers and virtual groups. Respondents were from different provinces (East and West Azerbāijān, Semnān, North Khorāsān, Khorāsān Razavi, and Tehran) and from different academic years.

Findings

٢٠٣ people answered the online test (١٢٠ females and ٨٣ males; mean age =٢٢,٦ & SD = ٣,٤). Most of the participants were freshmen (N=٨٧), and the least number of them were senior students (N = ٢٤).

In this section, the questionnaire's components of PCK and factor structures were examined. To answer the research questions, different statistical methods and tests were used through AMOS٢٤ and SPSS٢٥ software. To check the normality of the data, coefficients of Skewness and kurtosis were used. Pearson correlation coefficient has been used to investigate

the relationship among the variables, and path analysis has been used to examine the research questions and hypotheses.

Table ٢. Descriptive indicators of research scales

Variables	number of samples	Mean	Standard deviation	Minimum	Maximum
Knowledge of teaching strategies	٢٠٣	٢٥,٠٧	٥,٠٧	١١	٥٥
knowledge of Learner	٢٠٣	١٨,٢١	٣,٢١	٨	٤٠
Knowledge of curriculum	٢٠٣	٢١,٢٣	٤,٢٣	١٠	٥٠

As could be seen in the table ٢, the mean score of the respondents in terms of the knowledge of teaching strategies variable is ٢٥,٠٧ (SD =٥,٠٧), their mean score in terms of the knowledge of learner variable is ١٨,٢١ (SD =٣,٢١), and their mean scores in terms of the knowledge of curriculum variable is ٢١,٢٣ (SD = ٤,٢٣).

Measuring the normality of the distribution of variables

Table ٣. Results of the normality of the variables in the research

Variables	coefficient of Skewness		coefficient of kurtosis		Test result
	Statistics value	standard error	Statistics value	standard error	
pedagogical content knowledge	-٠,٥٥٦	٠,١٧١	-٠,٥٥٦	٠,٣٤٠	It is normal
Knowledge of teaching strategies	- ٠,٤٦٥	٠,١٧١	- ٠,٩٨٢	٠,٣٤٠	It is normal
Knowledge of learner	- ٠,٧٢٧	٠,١٧١	- ٠,٤١٦	٠,٣٤٠	It is normal
Knowledge of curriculum	- ٠,٧٥٩	٠,١٧١	- ٠,٧٤٨	٠,٣٤٠	It is normal

As it is clear in the table, the value of the skewness and kurtosis coefficient of all variables is between -٢ and ~~plus~~ +٢. Given that the skewness and kurtosis coefficients of the studied variables are all in the range of -٢ to +٢, it could be inferred that there is no violation of the normal distribution among the data. Therefore, it is inferred that the distribution of the data of the variables in the above table is normal or at least very close to normal.

Pearson correlation coefficient between variables

Table ٤. Pearson correlation test between variables

Variables		Knowledge of teaching strategies	Learner knowledge	Curriculum knowledge
Knowledge of teaching strategies	The value of correlation	١		
	Significance level	٠.		

knowledge of learner	The value of correlation	٠,٢٩١	١	
	Significance level	٠,٠٠	.	
Knowledge of curriculum	The value of correlation	٠,٢٦٦	٠,٢٩٤	١
	Significance level	٠,٠٠	٠,٠٠	٠

The analysis of variance (ANOVA) was used to study the level of PCK among students of different years. The results showed a significant difference between the level of PCK among students of different years and the amount of knowledge has been increased by the increament of years of study.

Confirmatory factor analysis of the questionnaire constructs

Since the topic of conceptual model fit and the indicators which could interpret the model fit in the best way possible are very diverse and complex, and researchers are faced with some confusion, in this section, six indicators (Chi-square/degree of freedom, root mean square error of approximation (RMSEA), normative fit index (NFI), comparative fit index (CFI), increment fit index (IFI), and goodness of fit indices (GFI)) used during the research, are shown in table ٦.

Table ٦. Model fit indices

Examined indices	Latin symbols	Standard value	
Chi Square / Degree of Freedom	($x^{٢}$/ df)	Less than ٣	Carmines & McIver (١٩٨١)
root mean square error of approximation	(RMSEA)	Less than ٠,٠٨	Hair et al (١٩٩٨)
normative Fit	(NFI)	More than ٠,٩	Bentler & Bonnet (١٩٨٠)
Comparative Fit	(CFI)	More than ٠,٩	
Incremental Fit	(IFI)	More than ٠,٩	
Goodness of fit	(GFI)	More than ٠,٨	Etezadi-Amolo & Farhoomand (١٩٩٦)

First-order confirmatory factor analysis of the PCK variable

The diagram below shows the model of first-order factor analysis.

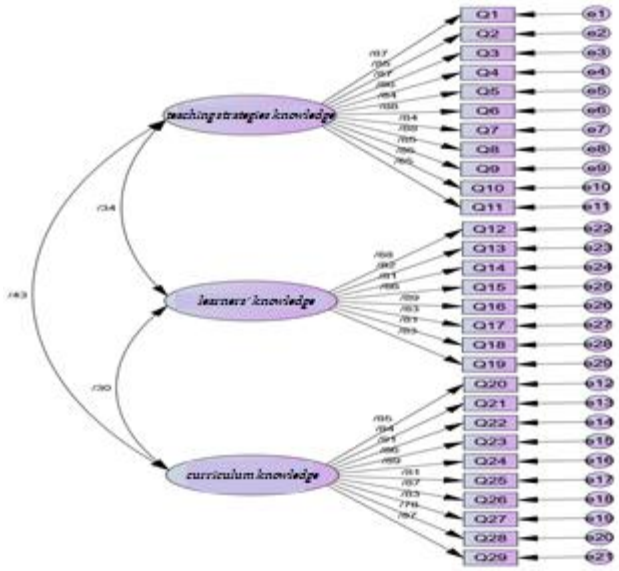

Diagram ١. Standardized factor loadings of the model of first-order factor analysis of PCK

Standardized coefficients of the factor loadings and the significance value of t

From the standardized coefficient measurement model, it could be deduced whether there is a significant correlation between the relevant latent variables and their corresponding indices or not. Standardized coefficients actually represent the path coefficients or standardized factor loadings between agents and indicators. In order to be valid, there must be a significant correlation between the variables and the questionnaire items. If the standardized factor loading is higher than ٠,٤, it could be said that the questions have good explanatory power. T-values show the significance of each parameter, and if the value of t is more than the absolute value of ١,٩٦, the model parameters are significant. In this way, the validity of the measurement constructs of the relevant variables could be confirmed at a significance level of ٠,٠٥.

Table ٧. Standardized factor loading value and t-statistics

Components	Questionnaire items	Standardized factor loading value	T value	Cronbach's alpha	Result
Knowledge of teaching strategies	I١	٠,٨٧٤	-	٠,٩٦٩	Optimal
	I٢	٠,٨٥٣	١٦,٨٨٩		Optimal
	I٣	٠,٨٧٤	١٧,٧٢٣		Optimal
	I٤	٠,٨٥٩	١٧,٠٩٥		Optimal
	I٥	٠,٨٣٩	١٦,٣١٣		Optimal
	I٦	٠,٨٧٨	١٧,٩٠٥		Optimal
	I٧	٠,٨٣٥	١٦,١٩٩		Optimal
	I٨	٠,٨٨٢	١٨,٠٧٩		Optimal
	I٩	٠,٨٥٠	١٦,٧٦٣		Optimal
	I١٠	٠,٨٥٠	١٦,٧٧٣		Optimal
	I١١	٠,٨٥٤	١٦,٩١٢		Optimal
Knowledge of learner	I١٢	٠,٨٧٨	-	٠,٩٥١	Optimal

	I١٣	٠,٨٢٣	١٥,٦٦٦		**Optimal**
	I١٤	٠,٨٠٥	١٥,٠٣٤		**Optimal**
	I١٥	٠,٨٥٨	١٦,٩٥١		**Optimal**
	I١٦	٠,٨٨٨	١٨,٢٢١		**Optimal**
	I١٧	٠,٨٢٨	١٥,٨٢٤		**Optimal**
	I١٨	٠,٨١٥	١٥,٣٥٥		**Optimal**
	I١٩	٠,٨٢٧	١٥,٨٠٦		**Optimal**
Knowledge of curriculum	I٢٠	٠,٨٤٩	-	٠٩٦٣	**Optimal**
	I٢١	٠,٨٣٨	١٥,٤٤١		**Optimal**
	I٢٢	٠,٩١٢	١٨,٠٩٥		**Optimal**
	I٢٣	٠,٨٥٨	١٦,١٠٥		**Optimal**
	I٢٤	٠,٨٨٨	١٧,١٤٦		**Optimal**
	I٢٥	٠,٨٠٩	١٤,٥٥٥		**Optimal**
	I٢٦	٠,٨٦٧	١٦,٣٩٩		**Optimal**
	I٢٧	٠,٨٢٩	١٥,١٥٤		**Optimal**
	I٢٨	٠,٧٧٦	١٣,٥٩٤		**Optimal**
	I٢٩	٠,٨٦٦	١٦,٣٧٠		**Optimal**

The dashed lines in the T values indicate fixing the parameter in the model.

As shown in table ٧, the factor loadings of all items were more than ٠,٤, and the t - values were more than ٠,٩٦. Therefore, the validity of the constructs is confirmed. Also, Cronbach's alpha coefficient of all components of PCK is estimated to be more than ٠,٧. So, no item needs to be removed from the model.

Model fit indices

To confirm the model of factor analysis and to document the results, it is necessary to fit the indices of the model to an acceptable level. Table ٨ shows the indices used along with their values.

Table ٨. Fit indices of the first-order factor analysis model of PCK

Examined indices	Latin symbol	Standard rate		Estimated value
Chi-Square / Degree of Freedom	($x^{٢}$/ df)	Less than ٣	Carmines & Mclaver (١٩٨١)	١,١٨٣
Root mean square error of approximation	(RMSEA)	Less than ٠,٠٨	Hair et al (١٩٩٨)	٠,٠٣٠
Comparative fit	(CFI)	More than ٠,٩		٠,٩٨
Increament fit	(IFI)	More than ٠,٩		٠,٩٨
Goodness of fit	(GFI)	More than ٠,٨	Etezadi-Amolo & Farhoomand (١٩٩٦)	٠,٨٨
Total Cronbach's alpha	(ALPHA)	More than ٠,٧	Cronbach (١٩٩٩)	٠,٩٥٣

As it could be seen in Table ٨, in the factor analysis model, the value of chi-square is ١,١٨ and less than ٣. Also, the RMSEA is ٠,٠٣ and less than ٠,٠٨. Also, the CFI, IFI, and GFI are all calculated at the appropriate level. Therefore, in general and according to the calculated indices, the optimal fit of the model could be concluded.

First-order confirmatory factor analysis of the PCK variable

The diagram below shows the model of second-order factor analysis.

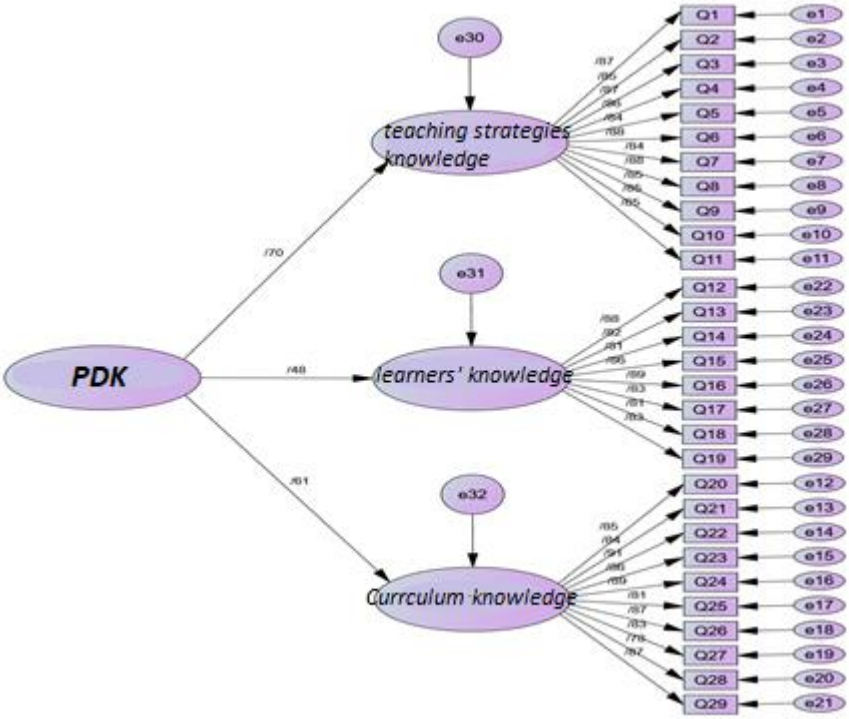

Figure ٢. Second-order confirmatory factor analysis model of PCK

Standardized coefficients of factor loadings and t-value significant level

The table below illustrates the t- value coefficients' significant level and the standardized path coefficients among the PCK and its components.

Table ٩. Standardized factor loading value and t-statistics among the variables

variable	components	value of standardized factor loading	T t-value	R^2	Cronbach's alpha	Result
pedagogical content knowledge	Knowledge of teaching strategies	٠,٦٩٥	٦,٣٩٦	٠,٤٨٤	٠,٩٥٣	Optimal
	Knowledge of learner	٠,٤٨٣	٥,٢٧٠	٠,٢٣٤		Optimal
	Knowledge of curriculum	٠,٦١٣	٥,٩٨٦	٠,٣٧٦		Optimal

As shown in Table ۹, the amount of t-statistics of PCK with its components is significant and is estimated to be more than ۱٫۹۶. Therefore, it is inferred that PCK can be divided into three subsets or sub-components. Cronbach's alpha coefficient of PCK (۰٫۹۵۳) is also calculated to be more than ۰٫۷, and it shows that the reliability of the constructs is at a desirable level.

Model fit indices

The table below shows the model fit indices:

Table ۱۰. Model fit indices of the second-order model of PCK

x۲/ df<۳	RMSEA<۰٫۰۸	CFI>۰٫۹	IFI>۰٫۹	GFI>۰٫۸
۱٫۱۸۳	۰٫۰۳۰	۰٫۹۸	۰٫۹۸	۰٫۸۸

As can be seen in the table above, the model fit indices are generally very desirable and at an acceptable level.

Ranking the components of PCK

The second-order confirmatory factor analysis model (Diagram ۲ and Table ۸) shows that the following components are of most to least importance in the PCK, respectively, including:

۱- Knowledge of teaching strategies variable with the factor loading of ۰٫۶۹ and the coefficient of determination (R۲) of ۴۸٪.

۲- Knowledge of curriculum variable with the factor loading of ۰٫۶۱ and the coefficient of determination (R۲) of ۳۷٪

۲- Knowledge of learner variable with the factor loading of ۰٫۴۸ and the coefficient of determination (R۲) of ۲۳٪.

The above results are graphically shown in terms of the factor loading of each component in the following diagram.

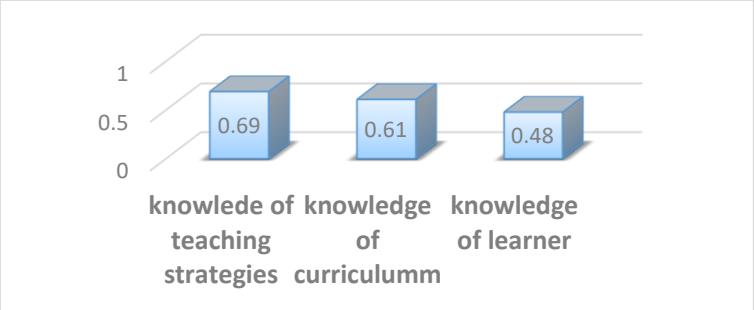

Figure ۳. ranking method of the components of PCK in terms of factor loading

Discussion

This study aimed to investigate the psychometric properties and factor structure of the PCK scale among primary education students at Farhangiān University. Findings showed the

appropriate construct validity of this tool and its ability to assess the PCK and its sub-components. Here, ٢٩ items measured the three factors, i.e., teaching strategies knowledge, knowledge of curriculum, and knowledge of learner. The Cronbach's alpha coefficient for the total score and each component was higher than ٠،٩٠, indicating the reliability and internal stability of the questinnare and the components. In short, findings of this study showed that this scale is a valid and reliable tool for determining the PCK of pre-service teachers.

Teachers need different knowledge and skills and effective teaching methods to plan and implement these programs in the classroom which would lead to students' understanding and learning. However, they not only need deep knowledge of the topic, education, curriculum, students, and knowledge of strategies; but also they should be able to apply this knowledge effectively while teaching. The PCK is a particular knowledge base for effective and useful teaching, which involves amalgamating knowledge and different skills of that knowledge. Courses and contexts of experiences and specific content methods are considered as contexts for teachers in developing their PCK. Generally, PCK helps the teachers gain control on the scientific nature of teaching-learning practices (Shulman, ١٩٨٧; Eilks & Markic, ٢٠١١). Teachers should know how to learn integrated teaching to achieve effective classroom teaching by focusing on the topic and content (Botha & Reddy, ٢٠١١). In this regard, Adunola (٢٠١١) claimed that teaching is a joint process that involves interaction, both by students and by the teacher. He also explained that recognizing the students' characteristics includes knowing who they are, what they know, and how students view the teacher's learning subject matter. The teacher should also be aware of each student's personal and educational background, especially the student's skills, abilities, and characteristics.

PCK is defined as an important combination of different types of knowledge. PCK includes basic knowledge in teaching, learning, curriculum, assessment, and reporting, such as the conditions that cause learning and the links among curriculum, assessment, and pedagogy (Koehler & Mishra, ٢٠٠٩). Moreover, PCK includes awareness of common misunderstandings and methods of examining them, the importance of linking among different content-based ideas, learners' prior knowledge, substituting teaching strategies, the flexibility due to examining the alternative methods, and examining similar ideas or problems for effective teaching. Therefore, teachers and student-teachers need PCK. When PCK is deeply analyzed, it can be considered an important assumption in the teaching process that could change the novice teachers to experienced teachers (Clermont et al., ١٩٩٤). Therefore, it is very important that teachers become aware of their PCK level. They can identify missing areas of their knowledge and try to increase their PCK level. Mishra & Koehler (٢٠٠٦) stated that the teachers who have correct understanding of the subject matter find another way to present that subject matter and allow learners to access them. In a study conducted by Chick et al. (٢٠٠٦) that included teaching techniques for teachers, the results showed that teachers demonstrated problem-solving skills and they benefited from a tool that measures students' learning about the subject. In his study, Westwood (٢٠٠٤) stated that while skilled teachers teach various practical styles, they all use pedagogical strategies to maximize student learning time and participation in learning tasks. In addition, they encourage students to participate actively in the class. Teachers also ensure that students understand what they need to do and assign tasks and activities at the appropriate level to ensure high success.

Regardless of the various interpretations of PCK, this knowledge is currently considered the best theoretical framework for examining and understanding the teachers' skills, organizing empirical data, documents, and exchanging ideas about teaching (Fernandez, ۲۰۱۳). Therefore, the study of teacher's PCK in different professions (primary education, trainees, novices, experienced, pre-service and in-service training, etc.) aims to provide contexts for teacher training. If the professional knowledge of good teachers could be accessed and it could be used as a citation, that knowledge could be used as a starting point for inexperienced teachers to utilize these experiences in their teaching. There is a consensus that the teacher training courses should be an explicit goal to develop teachers' PCK. During the early training, documents and skillful teachers could help the pre-service teachers become more efficient in the teaching process and they could help experienced teachers to develop more reflective methods, thereby further developing their PCK. There is ample evidence that PCK is a useful concept and instrument for describing and helping us understand teachers' professional methods. So, it could be said that this is a complex concept because the PCK is the result of very diverse human interactions in different situations. Although, pursuing the growth of PCK among novices, who have little idea of the education achievement, is challenging. However, the appeal of PCK lies in the ability that it could tell us something about the unique professional experience which acts as education.

However, data analysis about the three components of the PCK scale indicated that the component of knowledge of curriculum had the least correlation, and the component of knowledge of strategies had a more significant correlation. Many studies not only describe these components, but also examine the relationship among these components. Their findings show that there is interrelationship among the components of PCK and this is consistent with the results of the present study (Henze et al., ۲۰۰۸; Mohr & Townsend, ۲۰۰۲). Also, when the related literature is reviewed, it could be observed that the components of the proposed scale in this study are in line with the other studies. For example, the knowledge of teaching strategies has been considered in various studies (e.g., Ball & Sleep, ۲۰۰۷; Fernandez-Balboa & Stiehl, ۱۹۹۵; Grossman, ۱۹۹۰; Schoenfeld, ۱۹۹۸; Tamir, ۱۹۸۸; Toluk Uçar, ۲۰۱۰; YeSildere & Akkoç, ۲۰۱۰). Similarly, there are some studies in which the component of knowledge of learner is considered part of the PCK (e.g., Fernandez-Balboa & Stiehl, ۱۹۹۵; Grossman, ۱۹۹۰; Leavit, ۲۰۰۸; Schoenfeld, ۱۹۹۸; Tamir, ۱۹۸۸). Finally, many researchers have considered knowledge of curriculum as an important component of PCK (e.g., Grossman, ۱۹۹۰; Leavit, ۲۰۰۸; Schoenfeld, ۱۹۹۸; Tamir, ۱۹۸۸). Obviously the components of the scale are components of PCK which are defined by the related studies. Generally, this scale is considered as a useful tool for pre-service training of teachers, because it provides them with valuable information about the PCK. This tool on PCK is promising and it informs the teachers in what areas they need to progress. This scale could also be a useful tool for pre-service teachers in examining the possible perceptions of their teaching, content knowledge, and the related variables. Therefore, this scale is suggested to be implemented in more research and with different samples, such as students and in-service teachers, because more research greatly contributes to the greater application of the scale by considering the different components of PCK in various fields. As a result, the scale can be considered as a guide to determine the purpose of pre-service teachers in terms of their PCK. Furthermore, this scale can be used for the purposeful

studies, in-service teachers 'understanding of their teaching in various sciences, and designing teachers' professional development based on their needs.

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References

Mehrabani, N., Gooya, Z. (٢٠١٤). Design A Transitional Model from Professional Development (PD) Of Secondary Mathematics Teachers in Iran to Their Professional Learning (PL). *Journal of Curriculum Studies*, ٩(٣٤), ٣٥-٧٠.

Adunola, O. (٢٠١١). An analysis of the relationship between class size and academic performance of students. *Ego Booster Book: Ogun State, Nigeria*.

Akbari, R., & Dadvand, B. (٢٠١١). Does formal teacher education make a difference? a comparison of pedagogical thought units of B.A. versus M.A. teachers. *The Modern Language Journal*, ٩٥(١), ٤٤-٦٠.

Aksu, Z., Metin, M. (٢٠١٤). Develoment to of the pedagogical content knowledge scale for pre-service teachers: The validity and reliability study. *Mediterranean Journal of Social Sciences*, ٥(٢٠), ١٣٦٥-١٣٧٧.

Ball, D.L., & Sleep, L. (٢٠٠٧, January). *What is knowledge for teaching, and what are features of tasks that can be used to develop MKT*. In Presentation made at the center for proficiency in teaching mathematics (CPTM) pre-session of the annual meeting of the association of mathematics teacher educators (AMTE), Irvine, CA.

Baumert, J., & Kunter, M. (٢٠٠٦). Stichwort: Professionelle kompetenz von lehrkräften. *Zeitschrift für Erziehungswissenschaft*, ٩(٤), ٤٦٩–٥٢٠.

Baumert, J., & Kunter, M. (٢٠١٣). The COACTIV model of teacher professional competence. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss. & M. Neubrand (Eds), Cognitive activation in the mathematics classroom and professional compentence of teacher (pp.٢٥-٤٨). *Dordrecht, The Netherland: Springer.*

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., & Tsai, Y.-M. (٢٠١٠). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal*, ٤٧(١), ١٣٣–١٨٠.

Bentler, P.M., & Bonnet, D.C. (١٩٨٠). Significance Tests and Goodness of Fit in the Analysis of Covariance Structures. *Psychological Bulletin*, ٨٨(٣), ٥٨٨- ٦٠٦.

Blomeke, S. (٢٠١٧). Modelling teacher professional competence as a multi dimensional construct. In S. Guerriero (Ed.), *Pedagogical knowledge and the changing nature of the teaching profession* (pp. ١١٩-١٣٥). Paris, France: OECD Publishing.

Blömeke, S., Felbrich, A., & Müller, C. (٢٠٠٨). Teacher cognition in language teaching: A review of research on what language teachers think, know, believe, and do. *Language Teaching,* ٣٦(٢), ٨١-١٠٩.

Borg, S. (٢٠٠٣). Teacher cognition in language teaching: A review of research on what language teachers think, know, believe, and do. *Language Teaching,* ٣٦(٢), ٨١-١٠٩.

Botha, M.L. & Reddy, C.P.S. (٢٠١١). In-service Teachers' Perspectives of Pre-Service Teachers' Knowledge Domains in Science. *South African Journal of Education,* ٣١(٢), ٢٥٧-٢٧٤.

Bukova-Güzel, E., Cantürk-Günhan, B., Kula, S., Özgür, Z. & Nüket Elçi, A. (٢٠١٣). Scale development for pre-service mathematics teachers' perceptions related to their pedagogical content knowledge. *South African Journal of Education,* ٣٣(٢), ١-٢١.

Carlsen, W. S. (١٩٩٩). Domains of teacher knowledge. In J. Gess Newsome, & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. ١٣٣–١٤٤). Dordrecht: Kluwer.

Carmines, E.G. & McIver, J.P. (١٩٨١). Analyzing models with unobserved variables. In Bohrnstedt, G.W. & Borgatta, E.F. [Eds.] *Social measurement: Current issues*. Beverly Hills: Sage.

Chick, H. L., Baker, M., Pham, T., & Cheng, H. (٢٠٠٦). Aspects of teachers' pedagogical content knowledge for decimals. In J. Novotná, H. Moraová, M. Krátká, & N. Stehlíková (Eds.), *Proceedings of the ٣٠th annual conference of the International Group for the Psychology of Mathematics Education,* ٢, ٢٩٧-٣٠٤. Prague: PME.

Clermont, C. P., Borko, H., & Krajcik, J. S. (١٩٩٤). Comparative study of the pedagogical content knowledge of experienced and novice chemical demonstrators. *Journal of Research in Science Teaching,* ٣١(٤), ٤١٩–٤٤١.

Cochran-Smith, M., Villegas, A. M. (٢٠١٦). Research on teacher preparation: Charting the landscape of a sprawling field. In D. H. Gitomer, ٧ C.A. Bells (Eds.), *Handbook of research on teaching* (٥th ed., pp. ٤٣٩-٥٤٧). Washington, DC: AERA.

Cronbach, L.J., & Meehl, P.E. (١٩٥٥). Construct validity in psychological tests. *Psychological bulletin,* ٥٢(٤), ٢٨١.

Cronbach, L.J., & Shavelson, R.J. (٢٠٠٤). My current thoughts on coefficient alpha and successor procedures. *Educational and Psychological Measurement,* ٦٤(٣), ٣٩١-٤١٨.

Darling-Hammond, L. (٢٠٠٠). Teacher quality and student achievement. A review of state policy evidence. *Education Policy Analysis Archive,* ٨(١), ١–٤٤.

Darling-Hammond, L., Chung, R., & Frelow, F. (٢٠٠٢). Variation in teacher preparation: How well do different pathways prepare teachers to teach? *Journal of Teacher Education,* ٥٣(٤), ٢٨٦-٣٠٢.

Eilks, I., & Markic, S. (٢٠١١). Effects of a long-term participatory action research project on science teachers' professional development. Eurasia Journal of Mathematics. *Science and Technology Education,* ٧(٣), ١٤٩–١٦٠. doi:١٠,١٢٩٧٣/ejmste/٧٥١٩٦.

Eshter, M. (٢٠٠٨). Theacher views on understanding evolutionary theory: A PCK-Study in the Framwork of the ERTE-model. *Teaching and Teacher Education,* ٢٥(٢), ٢٥٩-٢٦٧.

Etezadi-Amolo, J., & Farhoomand, A.F. (١٩٩٦), A structural model of end user computing satisfaction and user performance. *Information and Management,* ٣٠ (٢), ٦٥–٧٣.

European Commission. (٢٠١٣). *Supporting teacher competence development for better learning outcomes.* Brussels, Belgium: European Commission.

Fernandez, C. (٢٠١٣). PcK - conhecimento pedagógico do conteúdo: perspectivas e possibilidades para a formação de professores (pcK - pedagogical content Knowledge: prospects and possibilities for teacher training. in: *Viii encontro nacional de pesquisa em educação em ciências – enpec*, ٢٠١١, Campinas, sp. Atas do VIII ENPEC – I CIEC ٢٠١١. rio de Janeiro, rJ: abrapec, ١, ١-١٢.

Fernandez-Balboa, J. M., Stiehl, J. (١٩٩٥). The generic nature of pedagogical content knowledge among college professors. *Teaching and Teacher Education,* ١١(٣), ٢٩٣-٣٠٦.

Feryok, A. (٢٠١٠). Language teacher cognitions: Complex dynamic systems? *Teaching and Teacher Education,* ٣٤(٢), ٢٧٢-٢٧٩.

Freeman, D. (٢٠٠٢). The hidden side of the work: Teacher knowledge and learning to teach. A perspective from North American educational research on teacher education in English. *Language Teaching*, ٣٥(١), ١-١٣.

Freeman, D., & Johnson, K. E. (١٩٩٨). Reconceptualizing the knowledge-base of language teacher education. *TESOL Quarterly,* ٣٢(٣), ٣٩٧-٤١٧.

Grossman, P. L. (١٩٩٠). The making of a teacher: Teacher knowledge and teacher education. *New York: Teachers College Press*.

Hair, J.F., Anaderson, R.E., Tatham, R.L., & Black, W.C. (١٩٩٨). *Multivariate data analysis*. Prentice Hall, London.

Hashweh, M.Z. (٢٠٠٥). Teacher pedagogical constructions: A reconfiguration of pedagogical content knowledge. *Teachers and Teaching: theory and practice,* ١١(٣), ٢٧٣-٢٩٢.

Henze, I., van Driel, J.H., & Verloop, N. (٢٠٠٨). Development of experienced science teachers' pedagogical content knowledge of models of the solar system and the universe. *International Journal of Science Education,* ٣٠(١٠), ١٣٢١–١٣٤٢. [CrossRef].

Hill, H. C., Ball, D. L., & Schilling, S. G. (٢٠٠٨). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education,* ٣٩(٤), ٣٧٢–٤٠٠.

Hudson, P., & Peard, R. (٢٠٠٦). *Mentoring pre-service elementary teachers in mathematics teaching*. EDU-COM ٢٠٠٦. International Conference. Engagement and Empowerment: New Opportunities for Growth in Higher Education, Edith Cowan University, Perth Western Australia, ٢٢-٢٤ November. Available at http://ro.ecu.edu.au/cgi/viewcontent.cgi?article=١٠٧٨&context=ceducom.

Hudson, P., & Skamp, K. (٢٠٠٣). Mentoring preservice teachers of primary science. *The Electronic Journal for Research in Science & Mathematics Education*, ٧(١). Available at http://wolfweb.unr.edu/homepage/crowther/ejse/hudson١.pdf. Accessed ١١ October ٢٠٠٩.

Koehler, M. J., & Mishra, P. (٢٠٠٩). What is technological pedagogical content knowledge?. *Contemporary Issues in Technology and Teacher Education*, ٩(١), ٦٠-٧٠.

Krauss, S., Brunner, M., Kunter, M., Baumert, J., Blum, W., Neubrand, M. & Jordan, A. (٢٠٠٨). Pedagogical content knowledge of secondary mathematics teachers. *Journal of Educational Psychology*, ١٠٠(٣), ٧١٦-٧٢٥. DOI: ١٠,١٠٣٧/٠٠٢٢-٠٦٦٣,١٠٠,٣,٧١٦.

Kumaravadivelu, B. (٢٠١٢). *Language teacher education for a global society: A modular model for knowing, analyzing, recognizing, and seeing*. New York: Routledge.

Leavit, T. (٢٠٠٨). *German mathematics teachers' subject content and pedagogical content knowledge.* Doctoral Dissertation.

Lortie, Dan C. (١٩٧٥). *School teacher: A sociological study*. Chicago: University of Chicago Press.

Magnusson, S., Krajcik, J., Borko, H. (١٩٩٩). Nature, sources and development of pedagogical content knowledge for science teaching. In J. Gess- Newsome and N.G. Lederman (Eds.), *Examining Pedagogical Content Knowledge*. (٩٥–١٣٢). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Mishra, P., & Koehler, M. J. (٢٠٠٦). Technological pedagogical content knowledge: A framework for integrating technology in teachers Knowledge. *Teachers College Record*, ١٠٨(٦), ١٠١٧–١٠٥٤.

Mohr, D. J., & Townsend, J. S. (٢٠٠٢). Using comprehensive teaching models to enhance pedagogical content knowledge. *Teaching Elementary Physical Education*, ١٣(٤.), ٣٢-٣٦.

Pajares, M. F. (١٩٩٢). Teacher beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, ٦٢(٣), ٣٠٧-٣٣٢.

Rowland, T., Huckstep, P., & Thwaites, A. (٢٠٠٥). Elementary teachers' mathematics subject knowledge: the knowledge quartet and the case of Naomi. *Journal of Mathematics Teacher Education*, ٨(٣), ٢٥٥-٢٨١.

Schleicher, A, (٢٠١٦). *Teaching excellence through professional learning and policy reform*. Paris, France: OECD.

Schoenfeld, A.H. (١٩٩٨). Toward a theory of teaching-in-context. *Issues in Education*, ٤(١), ١-٩٤.

Shulman, L. S. (١٩٨٦). Those who understand: Knowledge growth in teaching. *Educational Researcher*, ١٥(٢), ٤-١٤.

Shulman, L. S. (١٩٨٧). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, ٥٧(١), ١-٢٢.

Smith, K. (٢٠٠٥). Teacher educators' expertise: What do novice teachers and teacher educators say?. *Teaching and Teacher Education*, ٢١(٢), ١٧٧-١٩٢.

Tamir, P. (١٩٨٨) Subject matter and related pedagogical knowledge in teacher education. *Teaching and Teacher Education*, ٤(٢), ٩٩ – ١١٠.

Tatto, M. T., Schwille, J., Senk, S., Ingvarson, I., Rowley, G., Peck, R., Bankov, K., Rodriguez, M., & Reckase, M. (٢٠١٢). *Policy, practice, and readiness to teach primary and secondary mathematics in ١٧ countries*. Amsterdam: IEA, Findings from the IEA Teacher Education and Development Study in Mathematics (TEDS-M).

Tepner, O. & Dollny, S. (٢٠١٤). Measuring chemistry teachers' content knowledge: Is it correlated to pedagogical content knowledge. In: C. Bruguiere A. Tiberghien & P. Clément (Eds.), *Topics and Trends in Current Science Education, ٩th ESERA Conference Selected Contributions* (pp. ٢٤٣–٢٥٤).

Toluk Uçar, Z. (٢٠١٠). Sýnýf öðretmeni adaylarýnýn matematiksel bilgileri ve öðretimsel açýklamalarý. *In proceedings of ٩ Ulusal Sýnýf Öðretmenliði Eðitimi Sempozyumu*, ٢٠-٢٢ Mayýs, Elazýð, ٢٦١-٢٦٤.

Van Driel, J. H., de Jong, O. & Verloop N. (٢٠٠٢). The development of preservice chemistry teachers' pedagogical content knowledge. *Science Education*, ٨٦(٤), ٥٧٢-٥٩٠, ٢٠٠٢. DOI: ١٠,١٠٠٢/sce.١٠٠١٠.

Verloop, N., Van Driel, J., & Meijer, P. (٢٠٠١). Teacher knowledge and the knowledge base of teaching. *International Journal of Educational Research*, ٣٥(٥), ٤٤١-٤٦١.

Westwood, P. (٢٠٠٤). *Effective teaching to reduce educational failure* (Ph.D Dissertation). University of Hong- Kong

YeSildere, S., & Akkoç, H. (٢٠١٠). Matematik öðretmen adaylarýnýn sayý örüntülerine ilikin pedagojik alan bilgilerinin konuya özel stratejiler baðlamýnda incelenmesi. *Ondokuz Mayýs Üniversitesi Eðitim Fakültesi Dergisi*, ٢٩(١), ١٢٥-١٤٩.

Zahorik, J. A. (١٩٩١). Teaching style and textbooks. *Teaching and Teacher Education*, ٧(٢), ١٨٥-١٩٦.