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Design and validation of an instrument to determine the relationship between pedagogical content knowledge and practical work in science instruction

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Abstract

Research in science education has recognized the importance of pedagogical content knowledge (PCK) and its relationship to practical work. Although efforts have been made to characterize this relationship accurately, research in this field still needs to be completed. This article shows an instrument's design and validation process that aims to determine the perception of PCK elements and their incidence in the design, implementation, and evaluation of practical work in science teachers. The questionnaire was subjected to content validation by a panel of experts and a pilot study to evaluate its internal consistency through Cronbach's alpha. The construction and validation yielded an instrument of 30 items grouped into five categories: orientations toward science teaching, knowledge of the curriculum, knowledge of assessment, knowledge of students' understanding of science, and knowledge of instructional strategies. Reliability yielded a Cronbach's alpha value of 0.881, showing the development of a consistent and reliable instrument.

Keywords: practical work, validation, questionnaire, pedagogical content knowledge

INTRODUCTION

Pedagogical content knowledge (PCK) is a widely researched topic of interest in science education research. PCK is the knowledge that a teacher should have and that, together with the instructional practices associated with that knowledge, is intended to promote student learning of a particular concept of a science subject. Such knowledge is related to organizing, representing, and adapting a topic, problem, and question based on students' interests, misconceptions, and abilities (Bond-Robinson, 2005; Magnusson et al., 1999). Grossman (1990), Magnusson et al. (1999), and Shulman (1986, 1987) proposed a framework of PCK for science teachers that defined five categories: orientations to science teaching (OST), knowledge of students' understanding of science (SK), knowledge of science curriculum (CuK), knowledge of instructional strategies (ISK), and knowledge of assessment (AK). Since then, educational research aligned with this proposal has been responsible for conceptualizing, developing, explaining, and analyzing PCK in science teachers (Abell, 2007, 2008; Akinyemi & Mavhunga, 2021; Alvarado et al., 2015; Goes et al., 2020; Park & Chen, 2012; Park & Oliver, 2008; Sintema & Marban, 2021). Part of these developments has focused on identifying the role and relationship that practice has with PCK. In this sense, when PCK is used in teaching science practical work, a learning environment is generated that guides the teacher's actions in the teaching of a specific content or topic (Bond-Robinson, 2005).

In line with the above, one of the topics that has aroused great interest in science didactics, is practical work (Barolli et al., 2010; Carrascosa et al., 2006; Hernández-Millan et al., 2012; Rayistan et al., 2020; Wellhöfer & Lühken, 2022; Zorrilla et al., 2019). This is due to the relevance of experiential spaces in teaching and learning processes, as observation, inference, and

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Contribution to the literature

- This study identifies science teachers' perceptions around the elements of PCK in practical work.
- It provides a starting point in the development of teacher training programs, which generate processes of reflection of the elements of PCK in the design, implementation, and evaluation of practical work.
- It provides a validated instrument that can be used in the professional development of teachers with PCK for chemistry, biology, and physics teachers who design, implement, and evaluate practical work.

analysis of phenomena are put into practice (Bucat, 2004; Hofstein & Lunetta, 2004; Vladušić et al., 2020). For this purpose, real objects and materials are usually manipulated and observed (Abrahams & Millar, 2008). Researchers have reported that hands-on work can be classified as confirmatory, exploratory, discovery, and problem-based (Barberá & Valdés, 1996; Caamaño, 2003, 2004; Chen & Eilks, 2019; Hernández-Millan et al., 2012; Hofstein, 2015).

Another aspect that stands out in practical work is its intentionality in the classroom (Abrahams & Reiss, 2012; Tacoshi & Fernandez, 2014). That is, if the work is focused on the learning goals or the goals set by the teacher. Thus, in line with what the students have to do, as opposed to what they do and what they learn (Abrahams & Millar, 2008). One of the objectives of practical work commonly cited in the literature (Hofstein & Lunetta, 2004; Lunetta et al., 2007) is to lead students to develop skills in handling laboratory instruments, to help them to awaken interest in science, to acquire scientific knowledge, to develop critical thinking and to promote scientific attitudes and values (Abrahams, 2017).

In this sense, practical work is an activity that a person performs to understand the phenomena of nature in which systematic forms of reasoning are learned, which are transferred to problem situations and allow the student to emulate the scientific role of research. Related to the above, in the context of practical work, it is essential to highlight the role of the teacher and his/her effectiveness. These roles (teacher and his/her effectiveness) have been addressed in educational research processes (Abrahams & Millar, 2008; Abrahams & Reiss, 2012; Abrahams & Saglam, 2010). For example, effectiveness has been studied from students' perceptions and the point of view of the results obtained from the understanding of teaching strategies (Baladoh et al., 2017). Thus, teachers must be able to use the knowledge of the students and their understanding about the purposes of teaching science. In such a way, these generated strategies are effective, focused on learning (Tacoshi & Fernandez, 2014). Moreover, the purpose of teaching with practical work in science is to develop thinking skills in students, starting from the sources of scientific knowledge (Gericke et al., 2022; Wei & Liu, 2018). Regarding the teaching role, research has focused on the perception of the teacher's conception of practice (Alneyadi, 2019; Shana & Abulibdeh, 2020) and on the perspective of PCK (Grossman, 1990; Shulman, 1986; Wei & Liu, 2018). PCK is characteristic of the teacher as an educational professional (Shulman, 1986, 1987; van Driel et al., 2014). This knowledge of the teacher is the result of the experience that the teacher acquires over the years and the repertoires that he/she builds in the exercise of the profession (Abell, 2007; Grossman, 1990; Loughran et al., 2004). In identifying the elements of PCK, it is noteworthy that most of the reported works have been done qualitatively through classroom observations, documentary analysis, interviews, and case studies. In order to record and analyze the information from the context of the classroom and the teacher's perception, Loughran et al. (2004) proposed two instruments that allowed to record of the PCK in the exercise of pedagogical practice, which consist of guiding questions that consider the central ideas about teaching. These instruments collect the teaching objectives stated by the teacher, the students' conceptions and learning difficulties, the ways of approaching concepts, problems, and projects used by the teacher, and developing evaluation processes. The first instrument is called "content repertoires" (CoRe). The second instrument focuses on how the teacher materializes the CoRe and complements the answers to the guiding questions. It is called "repertoires of professional and pedagogical experience" (Pa-Pers) and consists of the answers to the CoRe instrument integrated with the evidence collected through interviews and classroom observations. These instruments are qualitative and allow to PCK elements to be captured without measuring them (Rollnick & Mavhunga, 2014). For example, in a case study, Wei & Liu (2018) recorded and analyzed PCK of a chemistry teacher in a hands-on classroom, where the participant had multidimensional and mixed orientations to teaching. The orientations shaped his knowledge of his students' learning, and the context significantly influenced his PCK. On the other hand, instruments have been designed, validated and implemented in which science teachers' perceptions have been characterized, firstly on the sources of PCK in teaching with practical work (Chen & Chen, 2021), and secondly on teachers' practical knowledge of practical work (Chen et al., 2022).

Despite these reports of evidence of PCK elements in practical work, it should be noted that these reports have focused on a specific area (China). Moreover, it makes few studies about PCK elements and their incidence in the design, implementation, and evaluation of practical work in science. This leads us, in line with research on the same topic (Wei & Liu, 2018), to argue as "necessary" the design of instruments that can account for these aspects.

Therefore, this article developed a questionnaire to identify the perception of PCK elements and their incidence in the design, implementation, and evaluation of practical work in science teachers.

MATERIALS AND METHODS

Initial Design of the Questionnaire

This study aimed to design and validated a questionnaire to identify the perceptions of science teachers about the components of PCK and its relationship with the design, implementation, and evaluation of practical work in science.

Two phases were implemented for the questionnaire design: Phase I was determined by selecting information in which the review and analysis of inputs previously used by another research were carried out. For this purpose, the contributions made by Chen and Chen (2021), Chen et al. (2022), Fan (2014), and Wei and Liu (2018) were considered. However, there was only a partial answer to the perception of PCK elements and their incidence in the design, implementation, and evaluation of practical work in science; therefore, the decision was made to design a new instrument.

Phase II was associated with the correlational aspect since the study variables were not intentionally manipulated. The purpose was to validate the questionnaire.

The questionnaire considers the components of PCK, which according to Magnusson et al. (1999), include: OST, CuK, AK, SK, and ISK.

The initial questionnaire consisted of thirty items. Each component consisted of six items and five variables. Each item has a 5-point Likert scale made up, as follows: 5: always, 4: almost always, 3: sometimes, 2: rarely, and 1: never.

Validation Procedure

The instrument was validated in order to verify its usefulness. For this purpose, the process of validation by expert judgment was used (Escobar-Pérez & Cuervo-Martínez, 2008). This subjection to expert judgment is characterized by the review of a specific number of experts who evaluate the items of the questionnaire and assess the level of adequacy of the items and the dimensions to be evaluated (Creswell & Creswell, 2018; Lester et al., 2014).

Each of the experts was provided with a matrix, which mentioned the intentions of the questionnaire, a brief explanation of the theoretical background, and the necessary instructions to carry out the validation. In addition, this matrix had a space for the experts to make observations and open comments on each item. The following aspects were considered: sufficiency, clarity, coherence, and relevance. Sufficiency refers that the items of the same dimension are sufficient to obtain the measurement of this dimension (Escobar-Pérez & Cuervo-Martínez, 2008). Each criterion was rated on a scale of 1 to 4, with "1" indicating that the criterion was not met; "2", low level; "3", moderate level; and "4", high level. The information obtained by each of the pairs was consolidated, the results were tabulated, and the consistency of the judges was analyzed. After collecting and consolidating the information from the judges, we proceeded, as follows:

1. Analysis of consistency among judges: for this analysis, frequency statistics (median and standard deviation) were determined to analyze the homogeneity obtained in the evaluations issued by the peer evaluators.
2. Item adequacy analysis: to assess the adequacy of the items to the content validity criteria, the "Aiken's V" coefficient (Aiken, 1980, 1985; Penfield & Giacobbi, 2004), which measures the relevance of each item, was determined. It considers the number of dimensions evaluated by the experts and the number of participating judges, giving an overall assessment of the designed questionnaire. This statistic helps make decisions regarding modifying or eliminating items from a questionnaire. The algebraic modification proposed by Penfield and Giacobbi (2004) was used to calculate it:

$$V = (X - l)/k\ (1), \quad (1)$$

where X is the evaluation average between judges on each item; l is the lowest possible value (in this case, 1); and k is the range of possible values on the scale used (4-1=3).

The value obtained ranges from 0 to 1, where 0 indicates no expert agreement and 1 indicates perfect agreement among the evaluators (Benarroch et al., 2021; Escurra Mayaute, 1988).

The criteria for determining whether an item is eliminated or changed were, as follows:

First, if the mean value is less than 3.2; second, if Aiken's V value is less than .75 (Aiken, 1985); and finally, the qualitative observations of the experts merit the need to change or delete an item.

Validation Participants

The choice of experts is an appropriate step to establish content validity (Escobar-Pérez & Cuervo-Martínez, 2008; Pedrosa et al., 2014). The experts have a training profile associated with the highest academic degree (PhD in education, science didactics, innovation, and research in didactics and science chemistry) and have an essential trajectory in the field of research in science education. 10 experts participated in this process.

Construct Validity

For construct validity, Kaiser-Meyer-Olkin (KMO) sample adequacy test was developed to verify the feasibility of the factor analysis. It was necessary to evaluate the relationship patterns of the items and to evaluate the behavioral patterns of the items. The correlation matrix allows us to observe the determinant of the matrix. When the value is close to zero, performing an association between items is not recommended. KMO index takes values between 0 and 1, and as a guide, the interpretation of the values are, as follows: <.5 unacceptable; between .5 and .6 poor; between .6 and .7 fair; between .7 and .8 good and >.8 excellent (Guisande et al., 2013). According to the value it takes, it is possible to determine whether it is possible to resort to factor analysis as a strategy in the scale validation process. Also, Barlett's sphericity test was performed, making it possible to analyze whether the variables are correlated.

Psychometric Properties of the Questionnaire

The level of reliability of the instrument was determined. Subsequently, the internal consistency analysis was performed, which refers to giving significance to each of the items, and for this purpose, Cronbach's alpha value was determined. Microsoft Excel ® version 2019 and SPSS ® version 29 were used to analyze the results.

Pilot Participants

A sample of 110 students and graduates of undergraduate programs in chemistry, master's degree in chemistry teaching, and master's degree in teaching of exact and natural sciences from three universities located in the city of Bogotá and from a university located in the city of Talca (Chile) were used to carry out this analysis. The population sample was primarily female (59%). The average age was 31.63±11.09. About 64% are chemistry graduates, and about 22% are graduates in the training process doing pedagogical practice. At least 4% have professional training other than education. Almost a quarter of the sample has postgraduate disciplinary training, 21% have postgraduate training in education and pedagogy, and 31% are considering pursuing a postgraduate degree in the short term. The most frequent range of teaching experience was between one and five years (55%). The instrument was provided to each participant through a Google Forms ® link.

RESULTS

Content Validation Analysis

The criterion with the best results was clarity (mean [M]= 3.530; standard deviation [SD]=.200; Aiken's V=.844). The criterion with the lowest results was sufficiency (M=3.400; SD=.205; Aiken's V=.810). **Table 1** shows results obtained from assessment of 10 experts.

Each item was analyzed individually based on the sufficiency, clarity, coherence, and relevance findings and the qualitative evaluations generated by the experts.

Table 1. Expert evaluation results

Item	Sufficiency			Clarity			Coherence			Relevance		
	M	SD	Aiken's V	M	SD	Aiken's V	M	SD	Aiken's V	M	SD	Aiken's V
OST1	3.4	.699	.800	3.6	.516	.867	3.6	.516	.867	3.9	.300	.967
OST2	3.5	.707	.833	3.7	.483	.900	3.3	1.059	.767	3.5	.671	.833
OST3	3.2	.789	.733	3.5	.707	.833	3.1	.876	.700	3.3	.781	.767
OST4	3.3	1.059	.767	3.4	.699	.800	3.5	.707	.833	3.2	.748	.733
OST5	3.5	.972	.833	3.5	.850	.833	3.5	.707	.833	3.4	.663	.800
OST6	3.3	.675	.767	3.1	.738	.700	3.3	.675	.767	3.2	.748	.733
CuK1	3.5	.700	.833	3.6	.699	.867	3.7	.675	.900	3.7	.675	.900
CuK2	3.7	.420	.900	3.8	.422	.933	3.8	.422	.933	3.8	.422	.933
CuK3	3.4	.720	.800	3.5	.972	.833	3.5	.972	.833	3.6	.966	.867
CuK4	3.8	.360	.933	3.8	.632	.933	3.8	.632	.933	3.9	.316	.967
CuK5	3.5	.800	.833	3.5	.972	.833	3.4	.966	.800	3.8	.422	.933
CuK6	3.5	.700	.833	3.5	.972	.833	3.5	.972	.833	3.6	.699	.867
AK1	3.5	1.080	.833	3.7	.949	.900	3.7	.949	.900	3.7	.949	.900
AK2	3.3	1.160	.767	3.5	1.080	.833	3.5	1.080	.833	3.5	1.080	.833
AK3	3.7	.949	.900	3.7	.949	.900	3.7	.949	.900	3.7	.949	.900
AK4	3.6	.966	.867	3.6	.966	.867	3.6	.966	.867	3.6	.966	.867
AK5	3.7	.675	.900	3.6	.699	.867	3.6	.699	.867	3.6	.699	.867
AK6	3.2	1.229	.733	3.5	.972	.833	3.4	.966	.800	3.5	.972	.833
SK1	2.9	1.287	.633	3.0	1.155	.667	2.9	1.101	.633	3.0	1.155	.667
SK2	3.7	.675	.900	3.6	.699	.867	3.7	.675	.900	3.6	.699	.867
SK4	3.5	.707	.833	3.4	.699	.800	3.5	.707	.833	3.4	.699	.800
SK5	3.2	1.033	.733	3.4	.699	.800	3.4	.699	.800	3.3	.675	.767
SK6	3.5	.972	.833	3.5	.972	.833	3.6	.966	.867	3.7	.675	.900

Table 1 (Continued). Expert evaluation results

Item	Sufficiency			Clarity			Coherence			Relevance		
	M	SD	Aiken's V	M	SD	Aiken's V	M	SD	Aiken's V	M	SD	Aiken's V
ISK1	3.5	.700	.833	3.7	.675	.900	3.7	.675	.900	3.8	.422	.933
ISK2	3.3	.840	.767	3.6	.966	.867	3.4	.966	.800	3.5	.707	.833
ISK3	3.1	1.080	.700	3.5	.972	.833	3.3	1.059	.767	3.2	1.033	.733
ISK4	3.3	.980	.767	3.6	.966	.867	3.4	1.075	.800	3.4	1.075	.800
ISK5	3.2	.960	.733	3.5	.972	.833	3.3	1.059	.767	3.3	1.059	.767
ISK6	3.5	.800	.833	3.6	.966	.867	3.6	.966	.867	3.6	.966	.867
Mean	3.4	.205	0.810	3.5	.169	.844	3.5	.201	.832	3.5	.233	.841

Table 2. Expert evaluation & proposed changes to SK1 item

"Initial item: Practical work promotes the use of materials from the student's daily life."			
Quantitative assessment			
Sufficiency	Clarity	Coherence	Relevance
M=2.90	M=3.00	M=2.90	M=3.00
SD=1.287	SD=1.155	SD=1.101	SD=1.155
Aiken's V=.633	Aiken's V=.667	Aiken's V=.633	Aiken's V=.667
Qualitative assessment			
"ARS: This is more of a procedural objective than a conceptual one, which is what the category measures. EFA: Expand on the idea of "materials of life ..." EGZ: Revise the wording. It corresponds to the plural in the verb "to promote." SFS: It is recommended to clarify what is stated in the category. MQG: Practical work promotes using materials and resources from the student's daily life, such as …"			
"Modifications: Item modifications were made on results obtained in quantitative evaluation concerning criteria."			
Item's final composition: Practical work promotes using materials & resources in the student's everyday environment.			

Table 3. Kaiser-Meyer-Olkin & Barlett's tests

Kaiser-Meyer-Olkin measure of sampling adequacy		.819
Bartlett's test for sphericity	Approximate Chi-square	1,216.910
	Gl	435
	Significance	<.001

As an example, **Table 2** shows the modifications for item SK1. This item obtained a value lower than .75 in clarity, sufficiency, coherence, and relevance.

Based on the results obtained from quantitative and qualitative evaluation of the pairs for each of the items, the test items that were modified were OST3, OST4, OST6, AK2, AK6, SK1, SK4, SK5, IK3, IK4, and IK5.

Construct Validation Analysis

Table 3 shows the results obtained from KMO test of sampling adequacy and Barlett's test of sphericity, which supports the factorial matrix.

The value obtained was .819, indicating a good correlation between the variables and allowing the factor analysis to be projected with the sample data. On the other hand, the instrument's significance with Barlett's sphericity value was less than .001, which confirms that the variables are sufficiently correlated due to the small significance values.

The statistical analysis associated with the variance allows us to confirm the existence of a data set, which is grouped into nine factors. These factors explain more than 65% of the total variance. It is also identified that nine eigenvalues exceed unity. The values obtained coincide with the subcategories of the PCK components. **Table 4** shows the analysis result associated with the variance between variables.

Based on the results obtained, the final version of the questionnaire is shown in **Table 5**.

Table 4. Analysis of total explained variance

Initial eigenvalues											
C	Total	% variance	Accumulated %	C	Total	% variance	Accumulated %	C	Total	% variance	Accumulated %
1	7.937	26.456	26.456	9	1.016	3.386	65.533	17	.565	1.882	85.534
2	2.196	7.320	33.776	10	.927	3.091	68.623	18	.508	1.695	87.228
3	1.942	6.473	40.249	11	.904	3.014	71.638	19	.442	1.472	88.700
4	1.625	5.415	45.664	12	.845	2.816	74.454	20	.426	1.421	90.122
5	1.406	4.685	50.349	13	.775	2.584	77.038	21	.406	1.354	91.476
6	1.286	4.286	54.636	14	.717	2.390	79.428	22	.380	1.265	92.741
7	1.157	3.856	58.492	15	.656	2.188	81.616	23	.377	1.257	93.998
8	1.097	3.655	62.147	16	.611	2.036	83.652	24	.341	1.136	95.134

Table 4 (Continued). Analysis of total explained variance

C	Total	% variance	Accumulated %	C	Total	% variance	Accumulated %	C	Total	% variance	Accumulated %
Initial eigenvalues											
25	.284	.945	96.079	27	.256	.854	97.876	29	.227	.756	99.428
26	.283	.943	97.022	28	.239	.795	98.672	30	.172	.572	100.000
Sums of loads squared by extraction											
1	7.937	26.456	26.456	4	1.625	5.415	45.664	7	1.157	3.856	58.492
2	2.196	7.320	33.776	5	1.406	4.685	50.349	8	1.097	3.655	62.147
3	1.942	6.473	40.249	6	1.286	4.286	54.636	9	1.016	3.386	65.533

Note. Extraction method: Principal component analysis

Table 5. Final version of questionnaire

Category	Subcategory	Code	Item
Orientations towards science education	Orientations towards science education	OST1	Practical work promotes the development of the student's scientific thinking.
		OST2	Practical work encourages the student to learn science.
		OST3	Practical work promotes students' curiosity.
		OST4	Practical work allows students to experiment with the natural environment.
		OST5	Practical work facilitates the learning of instruments, methods and procedures.
		OST6	In designing & implementing practical work, you encourage student to consider procedures.
Curriculum knowledge	Mandatory goals & component	CuK1	In designing & implementing practical work, you design guide for students.
		CuK2	In designing & implementing practical work, you use guidelines provided by textbooks.
		CuK3	In designing & implementing practical work, you use guidelines provided on the Internet.
	Goals & components by subject & curriculum	CuK4	In designing & implementing practical work, you consider curriculum standards, curriculum guidelines, & basic learning rights.
		CuK5	In designing & implementing practical work, attainment of students' learning achievements is promoted.
		CuK6	In designing & implementing practical work, curriculum compliance is promoted.
Assessment knowledge	Evaluation methods	AK1	Practical work promotes formative student evaluation.
		AK2	Practical work promotes & develops activities oriented to summative student evaluation.
	Evaluation criteria	AK3	Practical work promotes discussion with student about evaluation process.
		AK4	Practical work promotes self-evaluation of work done in laboratory.
		AK5	Practical work promotes feedback & adjustments to reports submitted by students.
		AK6	Practical work promotes improvement of student learning outcomes.
Students' understanding of science comprehension	Learning prerequisite	SK1	Practical work promotes use of materials & resources found in student's daily environment.
	Learning difficulties	SK2	In designing practical work, you explore students' preconceptions.
		SK3	In designing practical work, you consider students' preconceptions.
		SK4	In designing practical work, you consider learning difficulties faced by students.
		SK5	Throughout the practical work, you promote discussion and feedback of the results obtained among the students, as well as of the learning process.
		SK6	Designed practical work is in accordance with student's socio-cultural context.
Knowledge of pedagogical strategies	General subject outlines	ISK1	Practical work promotes students' teamwork.
		ISK2	The submission of practical work is done on an individual basis.
		ISK3	Student is asked to submit a pre-report of practical work & is given feedback.
	Strategies for approaching	ISK4	Awareness-raising activities are conducted prior to practical work.
		ISK5	The student is familiarized with scientific article production.
		ISK6	Practical work led to development of post-implementation feedback activities.

Reliability

The reliability of the instrument was assessed. For this purpose, an analysis of its internal consistency was carried out. Cronbach's alpha coefficient was determined and, based on the results obtained, concurrent criterion validity was performed through the total correlation of all items. The internal consistency assessment of the instrument yielded a Cronbach's alpha value of .881 for the entire pilot questionnaire, indicating high internal consistency (Taber, 2018). The results are presented in **Table 6**.

In obtaining the final version of the questionnaire, the decision was made to review the items for modification or elimination. Those that showed an increase in Cronbach's alpha values and had a low homogeneity index (r<.30) were reviewed. Seven items cause a slight increase in the alpha value if deleted.

As shown in **Table 7**, the items with these characteristics are CuK1, CuK2, CuK3, CuK3, AK2, IK2,

Table 6. Instrument reliability statistics

Cronbach's alpha	Number of items	Average	Variance	Standard deviation	Alpha rank if an item is deleted
.881	30	119.77	146.416	12.100	.873→.889

Table 7. Ratio statistics of each item to the total

Item	A*	B*	C*	D*	E*
OST1	115.45	139.130	.408	.500	.877
OST2	115.47	137.738	.511	.581	.876
OST3	115.33	137.488	.476	.592	.876
OST4	115.64	135.371	.514	.504	.875
OST5	115.44	136.285	.540	.565	.875
OST6	115.75	133.435	.594	.601	.873
CuK1	115.58	140.337	.300	.368	.880
CuK2	116.84	143.679	.097	.340	.884
CuK3	116.67	146.479	-.041	.252	.888
CuK4	115.64	138.894	.344	.387	.879
CuK5	115.49	136.491	.584	.585	.874
CuK6	115.71	138.300	.408	.502	.877
AK1	115.60	136.004	.542	.493	.875
AK2	115.99	139.899	.256	.415	.881
AK3	116.09	132.909	.591	.533	.873
AK4	115.82	132.572	.536	.609	.874
AK5	115.47	136.765	.501	.566	.875
AK6	115.52	137.536	.563	.559	.875
SK1	115.73	136.879	.496	.420	.876
SK2	115.64	137.628	.444	.546	.877
SK3	115.57	136.027	.499	.507	.875
SK4	115.61	136.534	.533	.528	.875
SK5	115.52	137.628	.461	.435	.876
SK6	115.90	134.293	.550	.498	.874
ISK1	115.48	137.775	.437	.412	.877
ISK2	116.67	137.488	.265	.351	.883
ISK3	116.15	138.169	.281	.401	.881
ISK4	115.95	134.474	.486	.461	.875
ISK5	116.02	139.798	.222	.302	.883
ISK6	115.68	135.393	.561	.594	.874

Note. A*: Scale mean if item deleted; B*: Scale variance if item deleted; C*: Corrected item-total correlation; D*: Squared multiple correlation; E*: Cronbach's alpha if item deleted

IK3, and IK5. However, because the elimination of the items would imply the loss of valuable information for the research process and a slight increase in the instrument's reliability, it was decided to keep all the questionnaire items.

Therefore, the 30 items described in **Table 7** for the final version of the questionnaire are maintained and organized according to the categories described in Magnusson et al. (1999).

DISCUSSION AND CONCLUSIONS

This article illustrates the validation process of a questionnaire related to the perception of high school science teachers of the elements of PCK and its incidence in the design, implementation, and evaluation of practical work in science.

Considering the obtained results, the thirty items were organized in nine components that refers to PCK categories and subcategories. In the generation of the items, PCK categories and subcategories suggested in Magnusson et al. (1999) were taken into account: OST. This topic is related to the purposes that are set out in the teaching of a topic or content and the purposes of designing and implementing practical work in science are defined (Hofstein & Lunetta, 2004); knowledge of the curriculum refers to the goals and components that are mandatory. There, the teacher outlines a learning subject, as well as knowledge of the curriculum, i.e., what students should know and the relationship that is established from the goals for the design and implementation of practical work.

Knowledge of evaluation, which are the ways that the teacher uses to evaluate his students, covering the aspects that are important to evaluate, as well as the selection of the contents that are evaluated and the methodologies that are used for this purpose. Furthermore, the criteria that are proposed for the evaluation of performance in science with practical work (Tacoshi & Fernandez, 2014).

SK covers what the teacher must know to promote the development of scientific knowledge in students, the prerequisites and learning difficulties that arise when designing and implementing practical work in the teaching and learning processes. And finally, ISK, which addresses the general schemes by subject and specific ones by theme, which are the strategies to approach the design and implementation of practical work, which are helpful to lead students to the understanding of specific concepts.

In addition, the instrument was reviewed by ten experts to evaluate its sufficiency, clarity, coherence, and relevance for content validation. The respective modifications were made based on the evaluations obtained for each item and the judges' comments. In this sense, it is interesting to note that there was high agreement among the judges in the evaluation of each of the items, which shows that the proposed items are clear, sufficient, coherent, and pertinent to evaluate the perception of teachers concerning the design, implementation, and evaluation of practical work in science.

The result obtained for Cronbach's alpha was .881, suggesting a high value of internal consistency. Furthermore, it indicates that the questionnaire can help to measure the perceptions of PCK elements and their incidence in the design, implementation, and evaluation of practical work in science teachers. This consistency value is comparable to the obtained in other studies conducted for the measurement of PCK elements in science teachers (Chen & Chen, 2021; Chen et al., 2022; Irmak & Yilmaz Tuzun, 2019).

The aforementioned comments have been presented an original validated instrument that allows identifying the perceptions of science teachers about the components of PCK and its relationship with the design, implementation and evaluation of practical work in science. Additionally, it allows teachers to have a process of reflection of pedagogical practices in the development of their teaching and learning processes with practical work, so that they can rethink and generate inputs that promote learning in students, as well as the development of scientific skills and attitudes (Alneyadi, 2019; Boyle, 2019; Hofstein & Lunetta, 2004; Tacoshi & Fernandez, 2014).

This instrument can be used as an input for the design and implementation of teacher professional development programs related to the design, implementation, and evaluation of practical assignments to gather teachers' perceptions and generate reflections on pedagogical practices, that can be applied to science teachers (chemistry, physics, and biology) who develop their teaching processes with practical work.

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REFERENCES

Abell, S. K. (2007). Research on science teacher knowledge. In S. K. Abell, & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 1119-1164). Routledge.

Abell, S. K. (2008). Twenty years later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education, 30*(10), 1405-1416. https://doi.org/10.1080/09500690802187041

Abrahams, I. (2017). Minds-on practical work for effective science learning. In *Science education* (pp. 403-413). Brill. https://doi.org/10.1007/978-94-6300-749-8_29

Abrahams, I., & Millar, R. (2008). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education, 30*(14), 1945-1969. https://doi.org/10.1080/09500690701749305

Abrahams, I., & Reiss, M. J. (2012). Practical work: Its effectiveness in primary and secondary schools in England. *Journal of Research in Science Teaching, 49*(8), 1035-1055. https://doi.org/10.1002/tea.21036

Abrahams, I., & Saglam, M. (2010). A study of teachers' views on practical work in secondary schools in England and Wales. *International Journal of Science Education, 32*(6), 753-768. https://doi.org/10.1080/09500690902777410

Aiken, L. R. (1980). Content validity and reliability of single items or questionnaires. *Educational and Psychological Measurement, 40*(4), 955-959. https://doi.org/10.1177/001316448004000419

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement, 45*(1), 131-142. https://doi.org/10.1177/0013164485451012

Akinyemi, O. S., & Mavhunga, E. (2021). Linking pre-service teachers' enacted topic specific pedagogical content knowledge to learner achievement in organic chemistry. *Chemistry Education Research and Practice, 22*(2), 282-302. https://doi.org/10.1039/d0rp00285b

Alneyadi, S. S. (2019). Virtual lab implementation in science literacy: Emirati science teachers' perspectives. *EURASIA Journal of Mathematics, Science and Technology Education, 15*(12), em1786. https://doi.org/10.29333/ejmste/109285

Alvarado, C., Cañada, F., Garritz, A., & Mellado, V. (2015). Canonical pedagogical content knowledge by CoRes for teaching acid-base chemistry at high school. *Chemistry Education Research and Practice, 16*(3), 603-618. https://doi.org/10.1039/c4rp00125g

Baladoh, S. M., Elgamal, A. F., & Abas, H. A. (2017). Virtual lab to develop achievement in electronic circuits for hearing-impaired students. *Education and Information Technologies, 22*(5), 2071-2085. https://doi.org/10.1007/s10639-016-9532-7

Barberá, Ó., & Valdés, P. (1996). El trabajo práctico en la enseñanza de las ciencias: Una revision [Practical work in science teaching: A review]. *Enseñanza de Las Ciencias* [*Science Education*], *14*(3), 365-379. https://doi.org/10.5565/rev/ensciencias.4212

Barolli, E., Laburú, C., & Guridi, V. (2010). Laboratorio didáctico de ciencias: Caminos de investigación [Science learning lab: Research pathways]. *Revista Electrónica de Enseñanza de Las Ciencias* [*Electronic Journal of Science Education*], *9*(1), 88-110.

Benarroch, A., Rodríguez-Serrano, M., & Ramírez-Segado, A. (2021). New water culture versus the traditional design and validation of a questionnaire to discriminate between both. *Sustainability (Switzerland), 13*(4), 2174. https://doi.org/10.3390/su13042174

Bond-Robinson, J. (2005). Identifying pedagogical content knowledge (PCK) in the chemistry laboratory introduction: Pedagogical content knowledge (PCK) in chemistry. *Chemistry Education Research and Practice, 6*(2), 83-103. https://doi.org/10.1039/B5RP90003D

Boyle, J. (2019). Teaching gravitational waves in the lower secondary school. Part III. Monitoring the effect of a STEM intervention on students' attitude, self-efficacy and achievement. *Physics Education, 54*, 025007. https://doi.org/10.1088/1361-6552/aaf771

Bucat, R. (2004). Pedagogical content knowledge as a way forward: Applied research in chemistry education. *Chemistry Education Research and Practice, 5*(3), 215-228. https://doi.org/10.1039/b4rp90025a

Caamaño, A. (2003). Los trabajos prácticos en ciencias [Practical work in science]. In M. P. Jiménez, A. Caamaño, A. Oñorbe, E. Pedrinaci, & A. De Pro (Eds.), *Enseñar ciencias* [*Teach science*] (pp. 95-118). Grao.

Caamaño, A. (2004). Experiencias, experimentos ilustrativos, ejercicios prácticos e investigaciones: ¿Una clasificación útil de los trabajos prácticos? [Experiences, illustrative experiments, practical exercises and investigations: A useful classification of practical works?] *Revista Alambique* [*Alembic Magazine*], *39*(8), 39.

Carrascosa, J., Gil Pérez, D., & Vilches, A. (2006). Papel de la actividad experimental en la educación científica [Role of experimental activity in science education]. *Caderno Brasileiro de Ensino de Física* [*Brazilian Physics Teaching Notebook*], *23*(2), 157-181.

Chen, B., & Chen, L. (2021). Examining the sources of high school chemistry teachers' practical knowledge of teaching with practical work: From the teachers' perspective. *Chemistry Education Research and Practice, 22*(2), 476-485. https://doi.org/10.1039/d0rp00246a

Chen, B., Chen, L., & Meng, X. (2022). Development and validation of an instrument to measure upper-secondary school science teachers' perceived practical knowledge about practical work. *Journal of Baltic Science Education, 21*(1), 26-37. https://doi.org/10.33225/jbse/22.21.26

Chen, X., & Eilks, I. (2019). An analysis of the representation of practical work in secondary chemistry textbooks from different Chinese communities. *Science Education International, 30*(4), 354-363. https://doi.org/10.33828/sei.v30.i4.13

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE.

Escobar-Pérez, J., & Cuervo-Martínez, Á. (2008). Validez de contenido y juicio de expertos: Una aproximación a su utilización [Content validity and expert judgment: An approach to its use]. *Avances en Medición* [*Advances in Measurement*], *6*, 27-36. https://doi.org/10.1016/0032-3861(78)90049-6

Escurra Mayaute, L. M. (1988). Cuantificación de la validez de contenido por criterio de jueces [Quantification of content validity by judges' criteria]. *Revista de Psicología* [*Psychology Magazine*], *6*(1-2), 103-111. https://doi.org/10.18800/psico.198801-02.008

Fan, L. (2014). *Investigating the pedagogy of mathematics: How do teachers develop their knowledge?* Imperial College Press. https://doi.org/10.1142/p940

Gericke, N., Högström, P., & Wallin, J. (2022). A systematic review of research on laboratory work in secondary school. *Studies in Science Education, 59*(2), 245-285. https://doi.org/10.1080/03057267.2022.2090125

Goes, L. F., Fernandez, C., & Eilks, I. (2020). The development of pedagogical content knowledge about teaching redox reactions in German chemistry teacher education. *Education Sciences, 10*(7), 170. https://doi.org/10.3390/educsci10070170

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. Teachers College Press.

Guisande, C., Vaamonde, A., & Barreiro, A. (2013). Tratamiento de datos con R, Statistica y SPSS [Data treatment with R, Statistica and SPSS]. *Universidad de Vigo*. https://www.editdiazdesantos.com/wwwdat/pdf/9788479789985.pdf

Hernández-Millan, G., Irazoque-Palazuelos, G., & López-Villa, N. (2012). ¿Cómo diversificar los trabajos prácticos?Un experimento ilustrativo y un ejercicio práctico como ejemplos [How to diversify practical work? An illustrative experiment and a practical exercise as examples]. *Educación Química* [*Chemistry Education*], *23*, 101-111. https://doi.org/10.1016/S0187-893X(17)30142-8

Hofstein, A. (2015). Forms of laboratory work. In R. Gunstone (Ed.), *Encyclopedia of science education* (pp. 563-564). Springer. https://doi.org/10.1007/978-94-007-2150-0

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-First century. *Science Education, 88*(1), 28-54. https://doi.org/10.1002/sce.10106

Irmak, M., & Yilmaz Tuzun, O. (2019). Investigating pre-service science teachers' perceived technological pedagogical content knowledge (TPACK) regarding genetics. *Research in Science and Technological Education*, *37*(2), 127-146. https://doi.org/10.1080/02635143.2018.1466778

Lester, P. E., Inman, D., & Bishop, L. K. (2014). *Handbook of tests and measurement in education and the social sciences*. Rowman & Littlefield.

Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, *41*(4), 370-391. https://doi.org/10.1002/tea.20007

Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. In S. K. Abell, & N. G. Lederman (Eds.), *Handbook of research on science education* (393-441). Psychology Press.

Magnusson, S. J., Borko, H., & Krajcik, J. S. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome, & N. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95-132). Springer. https://doi.org/10.1007/0-306-47217-1_4

Park, S., & Chen, Y.-C. (2012). Mapping out the integration of the components of pedagogical content knowledge (PCK): Examples from high school biology classrooms. *Journal of Research in Science Teaching, 49*(7), 922-941. https://doi.org/10.1002/tea.21022

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualization of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*(3), 261-284. https://doi.org/10.1007/s11165-007-9049-6

Pedrosa, I., Suárez-Álvarez, J., & García-Cueto, E. (2014). Evidencias sobre la validez de contenido: Avances teóricos y métodos para su estimación [Content validity evidence: Theoretical advances and estimation methods]. *Acción Psicológica* [*Psychological Action*], *10*(2), 3-18. https://doi.org/10.5944/ap.10.2.11820

Penfield, R. D., & Giacobbi, P. R. (2004). Applying a score confidence interval to Aiken's item content-relevance index. *Measurement in Physical Education and Exercise Science, 8*(4), 213-225. https://doi.org/10.1207/s15327841mpee0804_3

Rayistan, M. G., Borodina, M. A., Denisova, O. I., Bogachev, Y. S., & Sekerin, V. D. (2020). The effectiveness of using virtual laboratory workshops in online education of students studying the discipline "inorganic chemistry." *Periodico Tche Quimica* [*Tche Quimica Periodical*], *17*(36), 934-948. https://doi.org/10.52571/PTQ.v17.n36.2020.949_Periodico36_pgs_934_948.pdf

Rollnick, M., & Mavhunga, E. (2014). PCK of teaching electrochemistry in chemistry teachers: A case in Johannesburg, Gauteng Province, South Africa. *Educación Química* [*Chemistry Education*], *25*(3), 354-362. https://doi.org/10.1016/s0187-893x(14)70551-8

Shana, Z., & Abulibdeh, E. S. (2020). Science practical work and its impact on students' science achievement. *Journal of Technology and Science Education*, *10*(2), 199-215. https://doi.org/10.3926/JOTSE.888

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14. https://doi.org/10.3102/0013189X015002004

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-23. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Sintema, E. J., & Marban, J. M. (2021). Pre-service teachers' knowledge of identifying and clearing pupils' misconceptions about inverse and composite functions via vignettes. *EURASIA Journal of Mathematics, Science and Technology Education*, *17*(1), em1930. https://doi.org/10.29333/ejmste/9378

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education, 48*(6), 1273-1296. https://doi.org/10.1007/s11165-016-9602-2

Tacoshi, M. M., & Fernandez, C. (2014). Knowledge of assessment: An important component in the PCK of chemistry teachers. *Problems of Education in the 21st Century, 62*(1), 124-147. https://doi.org/10.33225/pec/14.62.124

van Driel, J. H., Berry, A., & Meirink, J. (2014). Research on science teacher knowledge. In N. G. Lederman, & S. K. Abell(Eds.), *Handbook of research on science education, volume II* (pp. 862-884). Routledge.

Vladušić, R., Bucat, R., & Ožić, M. (2020). Evidence of the development of pedagogical content knowledge related to chemical bonding during a course for preservice chemistry teachers. *Center for Educational Policy Studies Journal, 10*(1), 59-81. https://doi.org/10.26529/cepsj.783

Wei, B., & Liu, H. (2018). An experienced chemistry teacher's practical knowledge of teaching with practical work: The PCK perspective. *Chemistry Education Research and Practice, 19*(2), 452-462. https://doi.org/10.1039/c7rp00254h

Wellhöfer, L., & Lühken, A. (2022). Problem-based learning in an introductory inorganic laboratory: Identifying connections between learner motivation and implementation. *Journal of Chemical Education, 99*(2), 864-873. https://doi.org/10.1021/acs.jchemed.1c00808

Zorrilla, E., Morales, L., Mazzitelli, C. A., & Olivera, A. del C. (2019). Análisis de trabajos prácticos de laboratorio elaborados por futuros docentes de ciencias naturales [Analysis of practical laboratory work prepared by future teachers of natural sciences]. *Góndola, Enseñanza y Aprendizaje de Las Ciencias* [*Gondola, Teaching and Learning of Science*], *14*(2), 286-302. https://doi.org/10.14483/23464712.13750

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