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DEVELOPMENT AND VALIDATION OF AN INSTRUMENT TO MEASURE UPPER-SECONDARY SCHOOL SCIENCE TEACHERS' PERCEIVED PRACTICAL KNOWLEDGE ABOUT PRACTICAL WORK

Bo Chen,
Lijun Chen,
Xianhua Meng,
Minjie Yan,
Miaomiao Shen

Abstract. *Teachers' practical knowledge is closely related to teaching practice. The purpose of this research was to develop an instrument for assessing upper-secondary school science teachers' perceived practical knowledge about practical work. The development of this instrument was based on five components in the conceptual framework of PCK about practical work: orientations of practical work, knowledge of curriculum materials in practical work, knowledge of students in practical work, knowledge of educational strategies for practical work, and knowledge of assessment in practical work. After the questionnaire was developed, 636 Chinese upper-secondary school science teachers participated in this research voluntarily. The results from exploratory factor analysis, correlation analysis and confirmatory factor analysis provided sufficient evidence for the construct validity of instrument. The high Cronbach coefficient indicated that the instrument had good internal consistency reliability. Finally, an instrument with six factors and 25 items was documented. The instrument would benefit science teacher educators and researchers.*

Keywords: *instrument validation, pedagogical content knowledge, perceived knowledge, practical work*

Bo Chen
Nantong University, P. R. China
Lijun Chen
Guangzhou University, P. R. China
Xianhua Meng, Minjie Yan, Miaomiao Shen
Nantong University, P. R. China

Introduction

Practical work has long played a critical role in science education as a mean of understanding the natural world. In many countries, one distinguishing feature of science education from most other school subjects is that it involves practical work. Besides, in some countries where there is a tradition of conducting experiments in school science, teachers often regard practical work as central to the charm and efficacy of science education (Abrahams & Millar, 2008). Generally speaking, practical work refers to all kinds of hands-on activities that are carried out in laboratories or used in science teaching (Gott & Duggan, 2007). These activities can be demonstrations conducted by a teacher or students' laboratory work in small groups.

As we know, the effective teaching with practical work cannot be separated from teachers, and the practical knowledge of teachers is most closely related to teaching practice (Park et al., 2011). However, there are few research studies on the practical knowledge of teachers in practical work, especially the evaluation of teachers' practical knowledge. Hence, this research has developed a questionnaire to measure practical knowledge of science teachers in practical work. The significance of this research is to provide science teacher educators with a useful instrument to assess the practical knowledge of teachers in practical work, so as to improve teaching practices in the laboratory. This instrument can also be employed to assess the effectiveness of professional development training programs.

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Literature Review

Conceptualizing PCK about Practical Work

PCK is universally regarded as unique to the teaching profession. Shulman (1986) firstly proposed the concept of PCK and defined it as interwoven subject matter and pedagogy knowledge necessary for effective teaching. In belief, it embodies the integration of teachers' knowledge of both pedagogy and subject matter which distinguishes them from those content specialists. The PCK model of Shulman has been interpreted and developed by many scholars (e.g., Tamir, 1988; Cochran et al., 1993). Although there is still not a commonly acknowledged concept of PCK, there is a consensus that PCK is rooted in teachers' classroom practice, that is to say, PCK is essentially a kind of practical knowledge. (Van Driel et al., 2001). In addition, According to De Jong et al.'s (2002) hierarchical structure theory, PCK can be divided into three levels from macro to micro and from abstract to concrete, which are: general PCK, domain-specific PCK, and topic-specific PCK. General PCK is located at the macro level, which represents teachers' general cognition of how to teach a specific subject, including the teaching theory of the subject, commonly used teaching strategies and assessment methods, as well as macroscopic educational objectives. Domain-specific PCK is located at the meso level, which represents teachers' cognition of how to teach specific domains in a particular discipline. Topic-specific PCK is located at the micro level, which represents teachers' cognition of how to teach a specific concept area (e.g., ecological system and chemical equilibrium). For practical work, it has the characteristics of domain-specific and topic-specific. On one hand, practical work is a unique domain, composed of particular content and principles, which is quite different from subject knowledge; on the other hand, practical work is topic-specific because its implementation depends on specific laboratory activities. Based on these considerations, PCK was used to refer to teachers' practical knowledge about practical work.

As mentioned earlier, the concept of PCK has been interpreted and modified by many researchers (Kind, 2009). Drawing from the work of Grossman (1990) and Magnusson et al. (1999), Park and Oliver (2008a) identified the concept of PCK in science teaching, which is comprised of five components and organized them into a pentagonal form. These five components incorporated into this model ally with those initially proposed by Shulman (1986) and can be regarded as different components for developing PCK assessment tools (Park & Oliver, 2008b). Based on this consideration, Park and Oliver's (2008a) model was applied to this research, with some modifications made to accommodate to the field of practical work. In this research, the five components of PCK about practical work include: (a) orientations of practical work, referring to teachers' understanding and achievement of the goals for practical work; (b) knowledge of curriculum materials in practical work, referring to the design intention and the characteristics of arrangements of the laboratory activities in curriculum; (c) knowledge of students in practical work, referring to the knowledge that teachers have about students in practical work, including students' prior knowledge and ability and students' learning difficulties; (d) knowledge of educational strategies for practical work, referring to the knowledge that teachers possess about teaching strategies or teaching modes in practical work; and (e) knowledge of assessment in practical work, referring to knowledge that teachers have to evaluate the learning achievements of students in practical work, including different evaluation dimensions and evaluation methods.

Teachers' Perceived Knowledge

Generally speaking, the research on teachers' knowledge can be divided into two aspects: perceived knowledge and actual knowledge. Perceived knowledge refers to the perception of the knowledge that an individual has when he completes the task in a specific target field. (Tormala & Petty, 2007). Actual knowledge refers to the direct and explicit knowledge acquired by an individual when he completes the task in a specific target field. Hence, perceived knowledge belongs to the field of metacognition while actual knowledge belongs to the field of cognition (Dori & Avargil, 2015).

Teachers' perception of their own knowledge has an important influence on the formation of their cognition. According to Johnson (1994), The higher a person's level of perceived knowledge in a particular domain, the more likely he or she is to make greater efforts and thus achieve higher levels of achievement. Perceived knowledge also has implications for behavior. When a person has a higher level of perceived knowledge about a topic, attitudes are more predictive of behavior (Davidson et al., 1985). Therefore, MaKinster et al. (2010) proposed that the measurement of perceived knowledge of teachers could be replaced by the measurement of actual knowledge. Some research studies have shown that there is a close positive correlation between perceived knowledge and actual knowledge. For instance,

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Eija et al. (2017) explored the perceived and actual knowledge of primary school student teachers in Biology and found that the student teachers with high level of perceived knowledge tended to have a higher level of actual knowledge than those with low level of perceived knowledge. Moreover, in the research of Barton-Arwood et al. (2005), teachers' actual knowledge development and perceived knowledge development embodied similarity after a workshop aimed at improving teachers' teaching skills.

Research Focus

Based on the literature discussed above, it was argued that determining science teachers' perceived PCK about practical work can provide valuable information on the development of teachers' PCK about practical work in teacher education programs. Moreover, referring to earlier studies, self-reporting questionnaires were used to assess perceived knowledge (Irmak & Yilmaz Tüzün, 2019; Zelkowski et al., 2013). Hence, this research aimed to develop a questionnaire to measure teachers' perceived PCK about practical work. Specifically, the research question was set as: What is the empirical evidence for supporting the validity and reliability of the perceived PCK about practical work questionnaire?

Research Methodology

General Background

This research was a questionnaire survey. In this research, upper-secondary school science teachers' perceptions of their PCK about practical work were examined by the relevant questionnaire. In November and December 2019, data collection was from the upper-secondary school science teachers in 8 administrative districts of Guangzhou, China.

Development of the Instrument

The development of the questionnaire was divided into two stages. Stage 1 involved defining different scales of perceived PCK about practical work. According to the conceptual framework above, the essential components embodying perceived PCK about practical work were adopted to define five scales of this questionnaire: orientations of practical work (OPK), knowledge of curriculum materials in practical work (KCMPK), knowledge of students in practical work (KSPK), knowledge of educational strategies for practical work (KESPK) and knowledge of assessment in practical work (KAPK). OPK scale explores teachers' perceptions of their ability to achieve different goals for practical work. KCMPK scale measures teachers' perceptions of their understanding about laboratory teaching activities in curriculum. KSPK scale assesses teachers' perceptions of their understanding about students' prior knowledge, ability and learning difficulties in laboratory activities. KESPK scale explores teachers' perceptions of their ability to conduct specific procedures and strategies for laboratory activities. KAPK scale measures teachers' perceptions of their ability to assess students' achievements in practical work, including different evaluation dimensions and evaluation methods.

For the second stage, items were developed for above five scales. The items for each scale were compiled according to the specific definition or explanation of the scale to which they belong. Taking the OPK scale as an example, according to Hofstein and Lunetta (2004), the goals for teaching with practical work can be summarized into six aspects: (1) scientific concepts; (2) Scientific interest and motivation; (3) scientific practical skills (4) problem-solving ability; (5) scientific habits of mind; (6) understanding nature of science. Hence, six items about teachers' perceptions of their ability to achieve the above six goals were designed respectively. In order to ensure the content validity, three professors and a few upper-secondary school science teachers were consulted for their opinions on the design of items. This work helped to strengthen the matching of the items with related scales, and to revise the wording and expression of the questionnaire. For instance, in the OPK scale, all three professors think that mastering scientific methods should be one of the goals for practical work and should be added to the scale. Hence, we added the item "I can help students master the scientific methods" to the OPK scale. For another example, in the KESPK scale, several teachers recommended that the illustration of specific strategies should be reflected in the questionnaires so that they could better understand these strategies. Therefore, in the final version, we followed teachers' advice and included the description of the strategies.

Finally, there were 27 items in total, with 7 in the OPK, 3 in the KCMPK, 4 in the KSPK, 3 in the KESPK, and 10 in the KAPK. These items were presented in the appendix. The questionnaire consisted of instructions, demographic questions, and 27 items arranged in the disordered order in the Likert 5-point scale representing the degree of agreement.

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Participants

The participants in this research came from Guangzhou, China. The administrative districts of Guangzhou can be divided into three types: main urban districts, new urban districts, and suburban districts. The upper-secondary school science teachers in three main urban districts, three new urban districts, and two suburban districts were selected as the participants. 680 questionnaires were distributed, of which 44 were incomplete and therefore considered invalid. Hence, there were 636 valid questionnaires with a recovery rate of 93.5%. Then the 636 valid questionnaires were randomly divided into two equal portions (Sample 1 and Sample 2). Sample 1, which was used in the preliminary study for obtaining instrument structure information, including 318 teachers (105 males and 213 females) from three types of districts. Sample 2, which was used to cross-validate the structure derived from the preliminary study, including 318 teachers (123 males and 195 females) from three types of districts. The basic information of research participants was presented in Table 1.

Table 1
Basic Information of the Participants

	Sample 1		Sample 2	
	N	**P.C. (%)**	***N***	**P.C. (%)**
1. Types of district				
Main urban districts	104	32.7	94	29.6
New urban districts	111	34.9	127	39.9
Suburban districts	103	32.4	97	30.5
2. Gender				
Male	105	33.0	123	38.7
Female	213	67.0	195	61.3
3. Teaching age				
One to three years	59	18.6	72	22.7
Four to nine years	97	30.5	79	24.8
Ten years and above	162	50.9	167	52.5

Data Analysis

With the help of SPSS 23.0 and Amos 21.0, the research data was analyzed to explore construct validity and reliability of the instrument. First, exploratory factor analysis (EFA) was conducted on the rating data of Sample 1 to identify the factor structure. Secondly, confirmatory factor analysis (CFA) was conducted on the rating data of Sample 2 to examine the model provided by EFA. Finally, the rating data of Sample 2 was employed to test internal consistency reliability of the instrument.

Research Results

Construct Validation of Instrument

According to the steps of the data analysis, the data of Sample 1 were first employed to conduct EFA. The value of Bartlett's test of sphericity was 6744.944 ($p < .05$). The KMO value was .784. Referring to Pallant (2013), when the KMO value is higher than .60, researchers can continue the factor analysis. Hence, EFA was used to extract salient factors for these 27 items. Consequently, the principal axis factoring method extracted six factors. The factor pattern matrix obtained by Promax rotation was shown in Table 2. The cumulative variance of all six factors was high, which was 67.449%. Besides, the factor loading scores of all items on their respective factor were higher than .40.

As indicated in Table 2, items A10, A7, A9, A8, A6, A5, and A4 developed in KAPK scale belong to factor 1. These items examine teachers' perceptions of their ability to employ different dimensions to assess students' learning achievements in laboratory. Hence, it was concluded that factor 1 referred to "knowledge of dimensions of assessment in practical work". Items O7, O6, O5, O4, O3, O2, and O1 belong to factor 2 and all of them are about teachers' percep-

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tions of their ability to achieve different goals for teaching with practical work. Thus, factor 2 was labeled "orientations of practical work". Items S2, S1, S3, S4 from KSPK scale were found to belong to factor 3. Thus, factor 3 was named as "knowledge of students in practical work". Items L2, L3, and L1 from KCMPK scale were found to belong to factor 4. Thus, factor 4 was labeled "knowledge of curriculum materials in practical work". Items A3, A2 and A1 belong to factor 5 and all of them are about teachers' perceptions of their ability to employ different methods to assess students' learning achievements in laboratory. Hence, factor 5 was referred to "knowledge of methods of assessment in practical work". Finally, items I2, I3, and I1 belong to factor 6, which contains all items of KESPK scale. Thus, factor 6 was named "knowledge of educational strategies for practical work".

Table 2
Rotated Factor Matrix in EFA

Item	Factor loading					
	Factor 1	Factor2	Factor3	Factor4	Factor5	Factor6
A10	.916					
A7	.891					
A9	.884					
A8	.858					
A6	.751					
A5	.648					
A4	.643					
O7		.895				
O6		.888				
O5		.859				
O4		.843				
O3		.801				
O2		.638				
O1		.621				
S2			.917			
S1			.833			
S3			.781			
S4			.706			
L2				.977		
L3				.938		
L1				.900		
A3					.824	
A2					.780	
A1					.727	
I2						.985
I3						.722
I1						.466
Eigenvalue	5.634	5.469	4.091	3.168	2.747	2.009
% of variance	26.737	12.883	9.487	7.704	6.031	4.608
Cumulative %	26.737	39.620	49.107	56.810	62.841	67.449

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Furthermore, as Trochim and Donnelly (2006) proposed, for convergent validity, correlations between items of a particular construct should be high; for discriminant validity, correlations between items of different constructs should be low. Besides, they argued convergent validity and discriminant validity were achieved when an item was more correlated with other items in the same construct than it was with items of different constructs. By analyzing the correlation matrices in Table 3 and Table 4, it was found that all correlation coefficients between items within six factors were higher than those with others, which met this condition.

Table 3
Correlation Coefficient between Items of Factor 1, 2, and All Items

Items	A10	A7	A9	A8	A6	A5	A4	O7	O6	O5	O4	O3	O2	O1
A10		.742	.803	.714	.653	.559	.551	.227	.190	.147	.157	.143	.092	.144
A7	.742		.765	.749	.696	.658	.602	.191	.207	.261	.235	.264	.144	.215
A9	.803	.765		.711	.700	.564	.514	.181	.253	.150	.167	.216	.103	.104
A8	.714	.749	.711		.685	.526	.584	.147	.144	.229	.169	.174	.017	.108
A6	.653	.696	.700	.685		.627	.660	.279	.251	.286	.286	.316	.123	.245
A5	.559	.658	.564	.526	.627		.609	.236	.147	.220	.288	.180	.202	.209
A4	.551	.602	.514	.584	.600	.609		.255	.234	.298	.217	.249	.244	.348
O7	.227	.191	.181	.147	.279	.236	.255		.810	.742	.705	.672	.550	.548
O6	.190	.207	.253	.144	.251	.147	.234	.810		.784	.733	.702	.487	.447
O5	.147	.261	.150	.229	.286	.220	.298	.742	.784		.748	.717	.468	.503
O4	.157	.235	.167	.169	.286	.288	.217	.705	.733	.748		.703	.570	.544
O3	.143	.264	.216	.174	.316	.180	.249	.672	.702	.717	.703		.534	.534
O2	.092	.144	.103	.017	.123	.202	.244	.550	.487	.468	.570	.534		.663
O1	.144	.215	.104	.108	.245	.209	.348	.548	.447	.503	.544	.534	.663	
S2	.109	.287	.215	.093	.315	.316	.233	.080	.107	.178	.178	.208	.133	.173
S1	.191	.353	.235	.228	.360	.347	.212	.170	.151	.224	.234	.218	.235	.186
S3	.225	.377	.246	.264	.364	.264	.256	.098	.130	.154	.239	.180	.148	.204
S4	.294	.345	.278	.312	.394	.251	.257	.146	.178	.239	.267	.208	.089	.157
L2	.035	.040	.007	.035	.024	.101	.061	.145	.149	.167	.217	.224	.257	.126
L3	.057	.062	.044	.017	.081	.110	.068	.171	.157	.221	.246	.270	.250	.158
L1	.003	.021	.004	.022	.056	.026	.103	.118	.154	.134	.197	.275	.273	.151
A3	.121	.154	.165	.135	.196	.139	.263	.114	.077	.081	.125	.110	.202	.164
A2	.124	.193	.158	.134	.238	.210	.239	.153	.076	.073	.139	.123	.092	.128
A1	.233	.238	.138	.218	.304	.182	.255	.173	.151	.165	.111	.180	.172	.155
I2	.011	.020	.015	.046	.027	.019	.036	.039	.032	.054	.023	.027	.004	.087
I3	.046	.137	.047	.072	.097	.084	.137	.090	.105	.086	.139	.051	.098	.241
I1	.072	.081	.081	.084	.160	.086	.119	.156	.157	.156	.234	.157	.144	.249

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Table 4
Correlation coefficient between items of factor 3, 4, 5, 6, and all items

Items	S2	S1	S3	S4	L2	L3	L1	A3	A2	A1	I2	I3	I1
A10	.109	.191	.225	.294	.035	.057	.003	.121	.124	.233	.011	.046	.072
A7	.287	.353	.377	.345	.040	.062	.021	.154	.193	.238	.020	.137	.081
A9	.215	.235	.246	.278	.007	.044	.004	.165	.158	.138	.015	.047	.081
A8	.093	.228	.264	.312	.035	.017	.022	.135	.134	.218	.046	.072	.084
A6	.315	.360	.364	.394	.024	.081	.056	.196	.238	.304	.027	.097	.160
A5	.316	.347	.264	.251	.101	.110	.026	.139	.210	.182	.019	.084	.086
A4	.233	.212	.256	.257	.061	.068	.103	.263	.239	.255	.036	.137	.119
O7	.080	.170	.098	.146	.145	.171	.118	.114	.153	.173	.039	.090	.156
O6	.107	.151	.130	.178	.149	.157	.154	.077	.076	.151	.032	.105	.157
O5	.178	.224	.154	.239	.167	.221	.134	.081	.073	.165	.054	.086	.156
O4	.178	.234	.239	.267	.217	.246	.197	.125	.139	.111	.023	.139	.234
O3	.208	.218	.180	.208	.224	.270	.275	.110	.123	.180	.027	.051	.157
O2	.133	.235	.148	.089	.257	.250	.273	.202	.092	.172	.004	.098	.144
O1	.173	.186	.204	.157	.126	.158	.151	.164	.128	.155	.087	.241	.249
S2		.809	.650	.579	.178	.135	.111	.169	.191	.191	.099	.112	.162
S1	.809		.597	.586	.231	.237	.162	.184	.167	.269	.076	.053	.230
S3	.650	.597		.699	.089	.061	.096	.098	.176	.215	.034	.118	.115
S4	.579	.586	.699		.127	.180	.119	.055	.115.	.109	.084	.096	.138
L2	.178	.231	.089	.127		.864	.884	.144	.079	.165	.099	.079	.093
L3	.135	.237	.061	.180	.864		.850	.103	.068	.170	.119	.112	.106
L1	.111	.162	.096	.119	.884	.850		.151	.140	.197	.100	.080	.096
A3	.169	.184	.098.	.055	.144	.103	.151		.631	.600	.057	.052	.062
A2	.191	.167	.176	.115	.079	.068	.140	.631		.595	.142	.151	.053
A1	.191	.269	.215	.109	.165	.170	.197	.600	.595		.087	.090	.022
I2	.099	.076	.034	.084	.099	.119	.100	.057	.142	.087		.704	.483
I3	.112	.053	.118	.096	.079	.112	.080	.052	.151	.090	.704		.431
I1	.162	.230	.115	.138	.093	.106	.096	.062	.053	.022	.483	.431	

To determine the structure of the six-factor model, sample 2 was employed to conduct CFA by using Amos 21.0. Kline's (2005) recommendations were utilized as guidelines available for acceptable model fit in this research: CMIN/DF < 3.0, RMSEA < .08, CFI > .90, TLI > .90 and SRMR < .08.

The results of CFA showed an unacceptable model fit, as CMIN/df = 2.782, RMSEA = .084, CFI = .890, TLI = .873 and SRMR = .065. To improve model fit, the modification indices was examined. The covariances between error terms for item S3 and S4, and for item A10 and A9 were extremely high at 46.498 and 34.108, indicating that the variables measured by these items were highly correlated. For item S3 and S4, understanding students' learning difficulties in laboratory activities is the basis for understanding their abilities. For item A10 and A9, students often demonstrate their scientific habits of mind when solving problems related to science. Hence, adding the within-construct error

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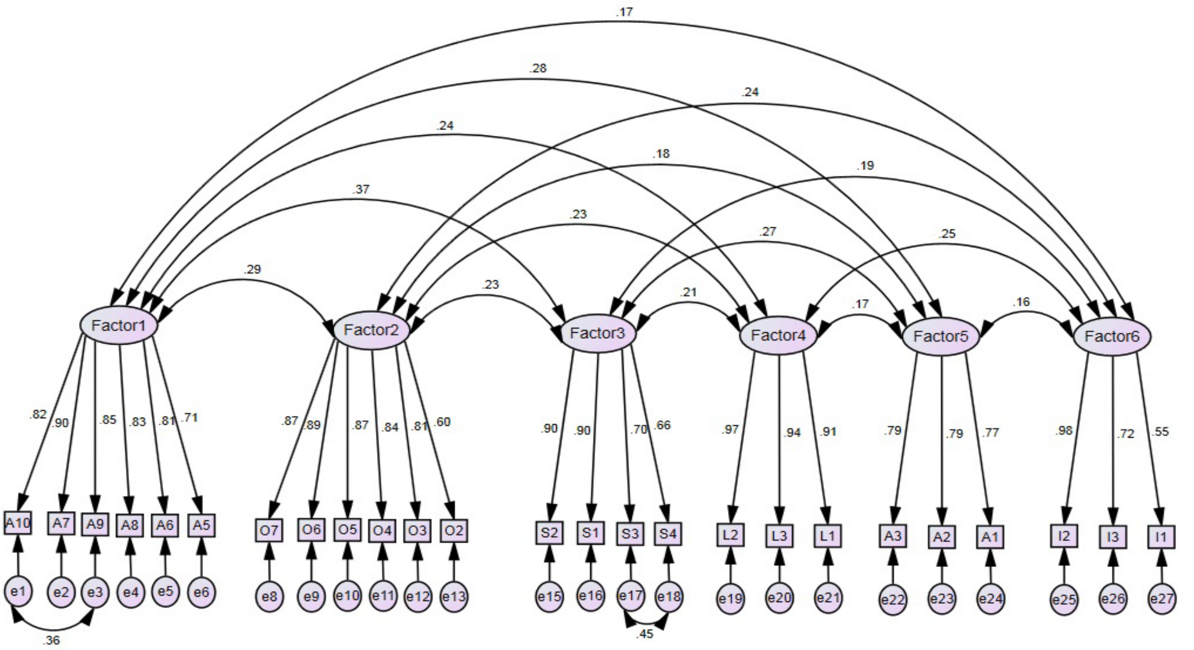
covariances between error terms of these items was reasonable. In addition, Byrne (2001) pointed out that the model was correct if the absolute value of most standardized covariances of residuals was less than three. The results showed four standardized residual covariances are relatively high: A4 and O5 (3.457), A4 and O2 (3.873), O1 and I3 (3.899), O1 and I1 (4.165). Hence, item A4 and O1 were deleted. CFA was rerun on the remaining 25 items. An acceptable model fit was revealed (CMIN/*df* = 2.267, RMSEA = .076, CFI = .927, TLI = .912, SRMR = .059). Figure 1 showed the CFA results of 25-item, six-factor scale.

Figure 1
The Six-factor Model



Reliability of Instrument

Sample 2 was employed to test internal consistency reliability of the instrument. As shown in Table 5, the Cronbach a coefficient for each scale was above .80 with good reliability (Taber, 2018). The overall Cronbach a coefficient of the instrument was .885, which means the instrument with six-factor and 25-item was reliable for assessing teachers' perceived PCK about practical work.

Table 5
The Cronbach a Coefficient for the Instrument

Scale	*N*	Cronbach a
Knowledge of dimensions of assessment in practical work	6	.927
Orientations of practical work	6	.922
Knowledge of students in practical work	4	.882
Knowledge of curriculum materials in practical work	3	.910
Knowledge of methods of assessment in practical work	3	.824
Knowledge of educational strategies for practical work	3	.811
Total	25	.885

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Discussion

This research developed and validated a questionnaire to measure upper-secondary school science teachers' perceived PCK of about practical work. Specifically, the questionnaire validation followed a two-phase approach. In the first phase, on the basis of the conceptual framework of PCK about practical work and the opinions from three professors and some upper-secondary school science teachers, the content validity of questionnaire was ensured. In the second phase, through conducting EFA with sample 1 as well as CFA and internal consistency reliability with sample 2, the construct validity and reliability of questionnaire were confirmed. EFA results showed that 27 items of the questionnaire can be extracted into six factors. These six factors were marked as "knowledge of dimensions of assessment in practical work", "orientations of practical work", "knowledge of students in practical work", "knowledge of curriculum materials in practical work", "knowledge of methods of assessment in practical work", and "knowledge of educational strategies for practical work" respectively. The research results supported the idea that the development of teachers' PCK was a complicated and multi-dimensional process, which needed to be fully cultivated and developed in each dimension (Magnusson et al., 1999; Van Driel et al., 2014).

In addition, both factors 1 and factor 5 contained the initial items of "knowledge of assessment in practical work" (KAPK) scale. Items of factor 1 focused on teachers' perceptions of their ability to employ different dimensions to assess students' learning achievements in laboratory, while factor 5 involved methods of assessment. The results showed that dimensions and methods of assessment form two different constructs for teachers, which means that it may be more appropriate to expand the conceptual framework of PCK about practical work from five components to six. Moreover, the correlation analysis showed that each scale measured a different construct. Therefore, the convergent validity and discriminant validity of the instrument was established.

Furthermore, The CFA results showed that item S3 was highly correlated with item S4 and item A10 was highly correlated with item A9, as well as items A4 and O1 should be deleted so as to improve the model fit. Items A4 and O1 are both about students' interest and motivation in science. Some research studies have shown that teachers' perception of students' motivation involves multi-dimensional constructs, which makes it difficult to measure (e.g., Hardre et al., 2008; Martin, 2006). Hence, items A4 and O1 were not presented in the final instrument. Thus, the final instrument contained 25-items in six scales. The results of this research demonstrated that using PCK to refer to teachers' practical knowledge about practical work is reasonable (Van Driel et al., 2001; De Jong et al., 2002) and science teachers' perceived PCK about practical work can be effectively measured by self-reporting questionnaires, which is consistent with the existing literature (Irmak & Yilmaz Tüzün, 2019; Zelkowski et al., 2013).

Conclusions and Implications

The main contribution of this research is to develop a valid and reliable instrument for assessing upper-secondary school science teachers' perceived PCK about practical work. In practice, this instrument is a convenient and valuable tool for both science teacher educators and researchers. For science teacher educators, acquired information on teachers' perceived PCK about practical work can guide them to improve teachers' practice in the laboratory. For researchers, this instrument can be employed in long-term research to examine changes in teachers' perceived PCK about practical work so as to assess the effectiveness of professional development programs related to laboratory work.

The limitation of this research should be noted. One limitation is the scope of application of the instrument. This instrument can be used to assess teachers' perceived PCK, but not actual PCK. Although perceived and actual knowledge are closely related, it is entirely possible that teachers do not have very precise judgments about the level of some components of their knowledge. In other words, while teachers' metacognition can provide valuable information on their PCK about practical work, it is not an absolute measure of the level of teachers' knowledge. Hence, in the future, it is still necessary to develop an instrument for assessing teachers' actual PCK about practical work. Another limitation of this research is the range of participants. This instrument was only tested in Chinese in Guangzhou. The validity and reliability of English version is uncertain. Therefore, it needs to be tested more widely in other countries and regions to verify its generality.

Declaration of Interest

The authors declare no competing interest.

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Appendix. List of items in the teachers' perceived PCK of teaching with practical work questionnaire

Orientations of practical work (OPK) scale:

Through teaching with practical work,
O1 I can arouse students' interest and motivation in science.
O2 I can develop students' scientific practical skills.
O3 I can promote students' understanding of scientific concepts.
O4 I can help students master the scientific methods.
O5 I can promote students' understanding of the nature of science.
O6 I can enlighten students' scientific habits of mind.
O7 I can improve students' ability in problem solving.

Knowledge of curriculum materials in practical work (KCMPK) scale:

L1 I know well about the requirement of practical work in curriculum standards.
L2 I know well about the characteristics of arrangements of laboratory activities in the curriculum materials.
L3 I know well about the design intention of laboratory activities in the curriculum materials.

Knowledge of students in practical work (KSPK) scale:

S1 I know well about students' prior knowledge in laboratory activities.
S2 I know well about the level of students' skills in laboratory activities.
S3 I know well about students' ability in laboratory activities.
S4 I know well about the students' learning difficulties in laboratory activities.

Knowledge of educational strategies for practical work (KESPK) scale:

In teaching with practical work,
I1 I can employ the direct instruction strategy very well.
I2 I can employ the inquiry strategy very well.
I3 I can select appropriate strategies according to teaching needs.

Knowledge of assessment in practical work (KAPK) scale:

For teaching with practical work,
A1 I can employ paper-and-pencil test to evaluate students' learning achievement.
A2 I can employ laboratory performance assessment to evaluate students' learning achievement.
A3 I can employ the assessment of students' laboratory report to evaluate students' learning achievement.

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A4 I can evaluate students' interest and motivation in science.
A5 I can evaluate students' scientific practical skills.
A6 I can evaluate students' understanding of scientific concepts.
A7 I can evaluate students' mastery of the scientific methods.
A8 I can evaluate students' understanding of the nature of science.
A9 I can evaluate students' scientific habits of mind.
A10 I can evaluate students' ability in problem solving.

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Bo Chen PhD, Associate Professor, School of Chemistry and Chemical Engineering, Nantong University, No.9, Seyuan Road, Nantong, P. R. China.
E-mail: njcb0128@aliyun.com
ORCID: https://orcid.org/0000-0001-5671-9223

Lijun Chen Master, School of Chemistry and Chemical Engineering, Guangzhou University, 230 Wai Huan Xi Road, Guangzhou Higher Education Mega Center, Guangzhou, P. R. China.
E-mail: Chenlijun_gzhu@163.com
ORCID: https://orcid.org/0000-0003-4185-6502

Xianhua Meng *(Corresponding author)* PhD, Professor, School of Educational Science, Nantong University, No.9, Seyuan Road, Nantong, P. R. China.
E-mail: mengxianhua@ntu.edu.cn
ORCID: https://orcid.org/0000-0003-4527-0808

Minjie Yan Master, School of Chemistry and Chemical Engineering, Nantong University, No.9, Seyuan Road, Nantong, P. R. China.
E-mail: 546566108@qq.com

Miaomiao Shen Master, School of Chemistry and Chemical Engineering, Nantong University, No.9, Seyuan Road, Nantong, P. R. China.
E-mail: 1369148638@qq.com