

# Accounting for Expertise: Unravelling the Effects of Training and Experience on Pedagogical Content Knowledge in High School Genetics Instruction

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**Abstract** Teaching experience and training are factors perceived to produce better pedagogical content knowledge (PCK). Therefore, this study examined their impact on PCK, involving 149 high school biology teachers in Ghana. Using Magnusson and colleagues' 1999 PCK framework, a 40-item questionnaire assessed PCK for teaching genetics. From the study there was no significant difference in the PCK of teachers in any of the components of PCK based on their teaching experience or training. However, differences existed in the way the components correlated with each other according to teaching experience and training. Training was found to improve PCK component interactions. However, teaching experience was found to improve interactions only within the first ten years of teachers' practice, beyond which it became hindering. The findings suggest teaching experience and training perhaps only significantly impact how teachers make interconnections between different knowledge bases and not their aptitude in the individual knowledge bases themselves.

**Keywords:** PCK, experience, training, teacher knowledge

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## 1. Introduction

Teacher knowledge has been found to have a positive impact on student performance [1,2,3] leading to the realization that teachers with appropriate knowledge have a greater impact on test scores of their students [2]. Consequently, the difference between having a good teacher and a bad one can exceed one grade-level equivalent in annual achievement growth [4]. A type of teacher knowledge that can affect student achievement is pedagogical content knowledge, or PCK [5].

An amalgamation of subject matter expertise and the ability to effectively teach students [6], PCK has gained relevance consequently because of its effect on teaching [7] and understanding [8]. A "good" PCK is considered an essential component of effective teaching and learning [9]. This in turn has had implications on teacher training and suggests that in looking at teacher knowledge, it's prudent to study pedagogical content knowledge especially when student performance is the concern.

Teachers with formal training are thus expected to possess superior PCK compared to content specialists, as

their training ideally equips them with content knowledge and pedagogical strategies to bridge the gap between content knowledge and classroom practice [10]. However, Fritsch et al. [11] noted that teacher training programs in Australia and Germany had little to no impact on prospective teachers' PCK, indicating a lack of consensus.

Teaching experience is another factor affecting PCK, with studies indicating a positive correlation between experience and PCK components and their interactions [10,12]. This implies that as teachers gain experience, their PCK tends to improve. However, some studies suggest no significant effect of teaching experience on pedagogical content knowledge [13], and there is a lack of consensus on how to measure and classify experience [14-16].

Rather than focusing exclusively on individual PCK components, it may be more useful to consider the interactions between these components [17]. In the context of Ghana, where students often face challenges with genetics concepts in examinations [18-21], understanding the PCK of genetics teachers at the senior high school level is crucial. Given the demonstrated impact of teachers' PCK on students' knowledge, particularly in Ghana where some Senior High school teachers may lack formal education training and have varying levels of teaching

experience [22], it is imperative to investigate how training and experience influence teachers' PCK.

*These research questions were thus considered.*

1. What is the difference in the genetics PCK components of Ghanaian SHS teachers based on their training?
2. What is the difference in the genetics PCK components of Ghanaian SHS teachers based on their teaching experience?
3. What are the interactions among the various components of Ghanaian SHS teachers' PCK for teaching genetics based on their training?
4. What are the interactions among the various components of Ghanaian SHS teachers' PCK for teaching genetics based on their teaching experience?

### **Theoretical framework**

Many researchers have offered various conceptualizations of PCK. One key conceptualization was done by Magnusson et al. [23]. They proposed PCK to comprise five types of knowledge and beliefs related to science teaching: orientations to teaching science (OTTS), knowledge of instructional strategies (KIS), knowledge of assessment (KAS), knowledge of students' understanding (KSU), and knowledge of curriculum (KSC).

OTTS guides instructional decisions, encompassing objectives, assignments, materials, and student evaluation [24,23]. Teaching orientations significantly impact the teaching and learning process, influencing pedagogical decisions [25]. KSC involves understanding vertical and horizontal curricula, linking students' prior and future learning experiences [26,27]. KAS on the other hand, includes grasping science learning dimensions and assessment methods, encompassing traditional and authentic approaches for diverse student expression [23] [28-31]. Furthermore, KSU entails awareness of students' conceptions, motivation, abilities, learning styles, interests, development levels, and needs [23,29,32]. Lastly, KIS involves subject and topic-specific strategies, aligning with general teaching goals and specific science concepts [23,29]. These strategies foster effective instruction and student engagement.

Magnusson et al.'s [23] framework has been effectively applied in assessing teacher PCK. For example, Can [33] utilized it to study the impact of lesson studies enriched with content representation on teachers' PCK. Sizer et al. [34] delved into the relationship between teachers' orientations and their implementation of inquiry-based learning approaches (KIS). Additionally, Ekiz-Kiran et al. [35] examined the effect of a school experience course on teachers' pedagogical content knowledge. Purwoko et al. [36] also investigated the influence of a PCK model on students' creativity in Mathematics learning. Lastly, Can and Boz [37] conducted a longitudinal study to scrutinize the changes in teachers' PCK across all five components during their teacher education training. These studies collectively affirm the efficacy of Magnusson's framework in evaluating and enhancing teacher PCK across diverse educational settings. Therefore, it's apt for this research to utilize the

framework in evaluating the PCK of Ghanaian teachers in teaching genetics.

## **2. Methodology**

### **Research Design**

A cross-sectional survey was used to collect data from 149 biology teachers without influencing their existing knowledge [38]. These teachers came from 43 schools randomly chosen from three regions in Ghana. All available biology teachers from each selected school were included in the study.

### **Data Collection Instrument**

A self-developed questionnaire was used to assess teachers' PCK for teaching genetics within Magnusson's framework. The questionnaire also gathered information on teachers' teaching experience and training. To evaluate their training, teachers indicated whether they had a professional teacher training degree (or diploma) or not. Teaching experience was classified as "under 1 year", "1 to 5 years", "6 to 10 years", or "more than 10 years".

The PCK items covered various dimensions corresponding to PCK subscales (orientations to teaching science (OTTS), knowledge of science curriculum (KSC), knowledge of students' understanding (KSU), knowledge of assessment in science (KAS), and knowledge of instructional strategies (KIS)). Each subscale's items were presented in a multiple-choice format, featuring a stem and four response options.

The OTTS subscale had items presenting genetics principles, with respondents selecting from four primary orientations: "didactic direct," "active direct," "guided inquiry," and "open inquiry" [39].

The KSU subscale comprised eight items covering genetics content with options reflecting different cognitive difficulty levels of students, encompassing recall, comprehension, application, and analysis. The goal was to assess which level of difficulty students had in the various topics under genetics.

The KAS subscale, investigating knowledge of assessment in science, consisted of seven items aiming to gauge the assessment techniques teachers would employ to evaluate students' performance on genetics-related themes.

The KIS subscale focused on knowledge of instructional strategies and consisted of seven items. Teachers indicated their approaches to teaching genetics concepts, choosing from four strategies: "a well-organized lecture," "classroom assignments," "class discussions among students," and "laboratory experiment". These strategies encompassed both student-centered and teacher-centered instructional techniques.

The KSC subscale explored knowledge of science curriculum and featured questions to determine whether teachers referred to vertical curriculum (past or future knowledge of students) or lateral curriculum (other science or non-science topics) when teaching genetics. This subscale comprised nine items.

### **Validity and Reliability of the Instrument**

Two genetics teaching experts and two pedagogical content knowledge specialists at the Senior High School

level, along with the researchers, assessed instrument items and structure for content validity. They ensured alignment with Magnusson et al.'s [23] proposed knowledge types for teaching genetics in Ghanaian SHS. Subsequently, a pilot test involving 30 biology teachers from an uninvolved region informed instrument refinement.

The reliability of the instrument in measuring the five components of PCK was assessed using Cronbach's alpha. All subscales obtained Cronbach's alpha values above 0.6, indicating their reliability [40,41]. Specifically, the OTTS subscale had a value of 0.654, the KSC subscale had a value of 0.73, the KSU subscale had a value of 0.692, the KAS subscale had a value of 0.686, and the KIS subscale had a high value of 0.939.

#### Data collection Procedure

The process involved initiating contact with school administration (headteachers or assistants) and presenting an introductory letter endorsed by the Department of Science Education, UCC. The study's nature was clarified, and access to teachers, the units of measurement, was requested. Teachers received information sheets and consent forms once ethical concerns were addressed. Those who agreed to participate were then provided with a questionnaire for independent completion.

#### Data Processing and analysis

Teachers' alignment with PCK components was assessed through response frequencies and means. Instead of a composite "PCK score," subscales provided varied

options, organized by increasing levels of cognition or student participation. Mean scores were calculated for each component based on teachers' alignment. These scores were used to explore relationships between different PCK components and to assess demographic differences. Mann-Whitney U or Kruskal-Wallis tests were applied to assess differences according to experience and training due to the ordinal nature of the data. Spearman's rank correlation coefficient was used to examine component relationships.

### 3. Results

The results from the data have been presented based on the research questions.

*Research question 1: What is the difference in the genetics PCK components of Ghanaian SHS teachers based on their training?*

Out of 149 respondents, 59 had no formal education training (NTE) while 90 had received training (TE) through a postgraduate diploma or higher in education. Teachers' choices under PCK components are categorized based on their training.

A Mann-Whitney U test was used to assess significant differences in PCK components based on education training. The analysis also examined the common ways teachers with different training applied PCK components (as shown in Table 2).

**Table 1. Teachers' application of different PCK components based on training in education**

Component	Application	NTE	TE
OTTS	Didactic direct	112	174
	Active direct	173	328
	Guided inquiry	154	204
	Open inquiry	92	104
	<b>Mean and SD</b>	<b>2.42 (sd=.573)</b>	<b>2.29 (sd=.442)</b>
KIS	A well-organized lecture	263	387
	Classroom discussions	67	106
	Lab experiment	55	89
	Take-home reading assignment	28	48
	<b>Mean and SD</b>	<b>1.63 (sd=.802)</b>	<b>1.68 (sd=.822)</b>
KAS	Paper and pencil-based tests	84	135
	Written take-home assignments	114	181
	Presentations by students	110	168
	Observe student performance on lab procedure	105	146
	<b>Mean and SD</b>	<b>2.57 (sd=.703)</b>	<b>2.51 (sd=.587)</b>
KSU	Remembering	79	122
	Understanding	131	205
	Application	137	201
	Analysis	125	192
	<b>Mean and SD</b>	<b>2.65 (sd=.637)</b>	<b>2.64 (sd=.561)</b>
KSC	Lateral curriculum (science)	136	221
	Lateral curriculum (non-science)	135	226
	Vertical curriculum backwards	175	212
	Vertical curriculum forward	85	151
	<b>Mean and SD</b>	<b>2.39 (sd=.598)</b>	<b>2.36 (sd=.575)</b>

**Table 2. Mann-Whitney U test of the effect of training in education on PCK components**

PCK Component	Training in Education	Mean Rank	Mann-Whitney U	df	Asymp. Sig.
OTTS	NTE	79.22	2406.0	1	0.332
	TE	72.23			
	Total				
KIS	NTE	72.18	2821.5	1	0.512
	TE	76.85			
	Total				
KAS	NTE	76.76	2551.0	1	0.686
	TE	73.84			
	Total				
KSU	NTE	76.27	2580.0	1	0.77
	TE	74.17			
	Total				
KSC	NTE	76.14	2588.0	1	0.794
	TE	74.26			
	Total				

The was no significant difference in the PCK of Ghanaian teachers in genetics according to their training in education. Specifically, teacher training in education had no significant impact on OTTS, KIS, KAS, KSU or KSC ( $p > 0.05$ ).

In looking at the specifics of where teachers aligned concerning training in education, when it comes to teaching orientation, both teachers with NTE and TE, mostly chose orientations which corresponded to active direct orientation. This is also consistent with the observed means for the two groups which were closer to 2.0 ( $\chi < 2.5$ )

which was the assigned code for active direct orientations. Ultimately, teachers in this study were more teacher-centered in their orientation regardless of training in education.

Likewise, teachers preferred to use a well-organized lecture in teaching the different topics under genetics. While the means for both groups were closer to the choice for “classroom discussions” ( $\chi > 1.5$ ) than “a well-organized lecture”, the most chosen instructional approach was teacher-centered. This suggests then that teachers’ KIS was thus more teacher-centered in its leanings than it was learner-centered.

For assessment, the most used form of assessment was written take-home assignments. However, it was by no means an overwhelming majority. Teachers preferred a whole range of assessment tools and generally clustered at about a mean of  $\chi \approx 2.5$ . This suggests that teachers were more neutral in their choice of authentic versus traditional assessment methods.

For knowledge of students’ understanding, NTE teachers chose application and TE teachers chose understanding as the levels of cognition students struggle with most in genetics. This means that both teachers identify higher cognitive tasks as areas students struggle with.

For knowledge of science curriculum, NTE teachers and TE teachers chose vertical curriculum (backward) and lateral curriculum (non-science) respectively as their preferred use of curriculum in their teaching. However, both means were closer to lateral curriculum nonscience ( $\chi < 2.5$ ) than they were to vertical curriculum (backward).

**Table 3. Teachers’ application of different PCK components based on teaching experience**

Component	Application	under 1 year	1 to 5 years	6 to 10 years	more than 10 years
OTTS	Didactic direct	47	180	49	10
	Active direct	62	301	102	36
	Guided inquiry	56	220	69	13
	Open inquiry	42	118	32	4
	<b>Mean and SD</b>	<b>2.45 (sd= 0.554)</b>	<b>2.33 (sd= 0.532)</b>	<b>2.33 (sd= 0.394)</b>	<b>2.17 (sd= 0.108)</b>
KIS	A well-organized lecture	91	397	122	40
	Classroom discussions	19	111	37	6
	Lab experiment	31	89	21	3
	take-home reading assignment	20	40	16	0
	<b>Mean and SD</b>	<b>1.87 (sd= 0.988)</b>	<b>1.64 (sd= 0.785)</b>	<b>1.65 (sd= 0.821)</b>	<b>1.24 (sd= 0.136)</b>
KAS	Paper and pencil-based tests	35	132	36	16
	written take-home assignments	43	182	53	17
	presentations by students	46	166	59	7
	Observe student performance on lab procedure	37	157	48	9
	<b>Mean and SD</b>	<b>2.53 (sd= 0.644)</b>	<b>2.54 (sd= 0.650)</b>	<b>2.61 (sd= 0.564)</b>	<b>2.18 (sd= 0.669)</b>
KSU	Remembering	33	128	32	8
	understanding	47	195	71	23
	Application	54	210	64	10
	Analysis	50	195	57	15
	<b>Mean and SD</b>	<b>2.66 (sd= 0.602)</b>	<b>2.64 (sd= 0.576)</b>	<b>2.65 (sd= 0.646)</b>	<b>2.57 (sd= 0.632)</b>
KSC	Lateral curriculum (science)	60	227	59	11
	Lateral curriculum (non-science)	64	200	83	14
	Vertical curriculum backwards	50	257	61	19
	Vertical curriculum forward	33	135	49	19
	<b>Mean and SD</b>	<b>2.27 (sd=0.566)</b>	<b>2.37 (sd= 0.596)</b>	<b>2.40 (sd= 0.580)</b>	<b>2.73 (sd= 0.410)</b>

*Research question 2: What is the difference in the genetics PCK components of Ghanaian SHS teachers based on their teaching experience?*

Teaching experience was categorized into four levels. Those who had “under 1 year, “1 to 5 years”, “6 to 10 years” and those with “more than 10 years” of teaching experience. Out of the 149 teachers, 23 of them had “under 1 year”, 91 had “1 to 5 years”, 28 had “6 to 10 years” and 7 had “more than 10 years” of teaching experience.

To answer the question of whether teaching experience had a significant impact on teachers' PCK, a Kruskal-Wallis test was organized (Table 4) as the data was not normally distributed.

**Table 4. Kruskal-Wallis test of the effect of teaching experience on PCK components**

PCK Component	Teaching experience	Mean Rank	Kruskal-Wallis H	df	Asymp. Sig.
OTTS	Under 1 year	82.17	1.205	3	0.752
	1 to 5 years	73.41			
	6 to 10 years	76.80			
	More than 10 years	64.86			
KIS	Under 1 year	81.65	2.911	3	0.406
	1 to 5 years	74.54			
	6 to 10 years	76.80			
	More than 10 years	50.64			
KAS	Under 1 year	74.35	2.989	3	0.393
	1 to 5 years	75.32			
	6 to 10 years	80.88			
	More than 10 years	49.50			
KSU	Under 1 year	74.93	0.130	3	0.988
	1 to 5 years	75.06			
	6 to 10 years	76.20			
	More than 10 years	69.64			
KSC	Under 1 year	67.67	3.337	3	0.343
	1 to 5 years	74.32			
	6 to 10 years	76.64			
	More than 10 years	101.29			

Consistent with the other demographic, teaching experience had no significant impact on the PCK of the teachers. From the results of the Kruskal-Wallis test, (OTTS:  $H(3) = 1.205$ ,  $p = 0.752$ , KIS:  $H(3) = 2.911$ ,  $p = 0.406$ , KAS:  $H(3) = 2.989$ ,  $p = 0.393$ , KSU:  $H(3) = 0.130$ ,  $p = 0.988$ , and KSC:  $H(3) = 3.337$ ,  $p = 0.343$ ) we can conclude that there is no statistically significant difference in PCK between the four groups of teachers with different levels of experience.

In examining teachers' teaching orientations, it was found that teachers predominantly favored an active direct orientation. This is also reflected again in the means which were all closer to 2.0 and suggested that teacher-centered orientations were the most dominant among these teachers.

Similarly, for KIS, teachers showed a preference for well-organized lectures in teaching genetics, which were teacher-centered. The means of teachers were also all below 2.0, indicating a preference for teacher-centered instructional strategies.

In terms of assessment, teachers oscillated between “written take-home assignments” and “presentations by students.” This perhaps indicates that teachers are willing to use a wide variety of authentic and traditional methods in assessing their students. This was the case for all teachers regardless of their teaching experience.

Regarding students' understanding, teachers identified application and sometimes analysis as the levels of cognition where students struggle the most in genetics. In terms of their KSC, teachers, regardless of teaching experience preferred the use of lateral curriculum when teaching their learners.

The results show, that for each of the components of PCK, teaching experience had no significant effect ( $p > 0.05$ ). Experienced teachers and novice teachers did not differ significantly in their mean ranks for each of the components of PCK and by these results should possess similar KSU, OTTS, KIS, KAS and KSC.

**Relationship between PCK components**

This section explores variations in PCK by scrutinizing interactions between its components, contingent on training and experience. Spearman's rank correlation was employed for assessment. As per Gignac and Szodorai's [42] adjustments to Cohen's effect size classification for non-normally distributed data, correlations of 0.15, 0.25, and 0.35 are deemed small, medium, and large, respectively.

*Research question 3: What is the interaction between the various components of Ghanaian SHS teachers' PCK for teaching genetics based on their training?*

The correlation matrices of PCK component interactions of both teachers who had “no training in education” and a “postgraduate diploma or higher in education” were compared to notice differences in correlation.

**Table 5. Spearman's rank correlation of PCK components for teachers trained and untrained in education**

		OTTS	KIS	KAS	KSU	KSC
No training in education	OTTS	1				
	KIS	.297*	1			
	KAS	0.001	0.152	1		
	KSU	-0.101	0.21	0.229	1	
	KSC	0.008	-0.085	-0.114	-0.061	1
Postgraduate Diploma or higher in education	OTTS	1				
	KIS	.247*	1			
	KAS	-0.028	0.201	1		
	KSU	0.097	0.158	-0.066	1	
	KSC	.290**	0.017	0.114	-0.196	1

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

As shown (Table 5), Teachers with no training in education demonstrated only one interaction between PCK components. Specifically, there was a significant, medium, ( $p < 0.05$ ,  $r > 0.25$ ) positive relationship between OTTS and KIS. On the other hand, teachers who had a postgraduate

diploma or higher in education made two interactions between PCK components. This was shown by a highly significant, positive, medium ( $p < 0.01$ ,  $r > 0.25$ ) relationship between OTTS and KSC and a significant and small relationship ( $p < 0.05$ ,  $r > 0.15$ ) between OTTS and KIS.

*Research question 4: What is the interaction between the various components of Ghanaian SHS teachers' PCK for teaching genetics based on their teaching experience?*

The correlation matrices of PCK component interactions based on teaching experience were also compared.

**Table 6. Spearman's rank correlation of PCK components for teachers based on teaching experience**

YEARS		OTTS	KIS	KAS	KSU	KSC
under 1 year N=23	OTTS	1.000				
	KIS	0.292	1.000			
	KAS	-0.025	0.245	1.000		
	KSU	-0.117	0.244	0.218	1.000	
	KSC	.487*	0.315	0.285	-0.027	1.000
1 to 5 years N=91	OTTS	1.000				
	KIS	.301**	1.000			
	KAS	-0.033	0.148	1.000		
	KSU	0.085	.248*	0.118	1.000	
	KSC	0.117	0.104	0.112	-0.015	1.000
6 to 10 years N=28	OTTS	1.000				
	KIS	0.145	1.000			
	KAS	0.016	0.082	1.000		
	KSU	-0.069	-0.076	0.013	1.000	
	KSC	.396*	0.099	0.258	-.518**	1.000
More than 10 years N=7	OTTS	1.000				
	KIS	0.217	1.000			
	KAS	-0.179	0.676	1.000		
	KSU	-0.048	0.110	0.587	1.000	
	KSC	-0.397	0.010	0.318	-0.376	1.000
*. Correlation is significant at the 0.05 level (2-tailed).						
**. Correlation is significant at the 0.01 level (2-tailed).						

A single interaction was observed between PCK components of teachers with "under 1 year" of teaching experience. This interaction was however a large, significant positive relationship between OTTS and KSC. With teachers who had "1 to 5 years" of teaching experience, there were two significant positive interactions observed specifically between OTTS & KIS and KIS and KSU. Both interactions were medium ( $r > 0.25$ ).

Teachers with "6 to 10 years" of teaching experience also made two significant, large connections. Specifically, these were observed between OTTS & KIS and KSC & KSU. However, the interactions between KSC & KSU were negative whilst that of OTTS & KIS was positive.

Those with "more than 10 years" of teaching experience, however, had no significant interactions between PCK components.

## 4. Discussion

### *Differences in PCK of teachers by components*

In looking at the difference in PCK, the results of this study suggest that at least for the teaching of genetics in Ghanaian senior high schools, there was no significant difference in where teachers aligned in the different components of PCK based on training, described as training in education or training as a major, and teaching experience.

The findings of this study have implications for professional teacher training and development. If PCK is the professional knowledge that sets teachers apart from content specialists, as suggested by Kind [43] and Berry et al. [44], there should be a difference between the PCK components of trained and untrained teachers. But this research suggests that there is no difference in the PCK components of teachers based their training. Others, like Fritsch et al. [11] also found that teacher training had no significant impact on teachers' PCK. Conversely, others [10], also report that teacher training leads to higher PCK levels in teachers.

The same goes for teaching experience. This study identified no significant difference in the PCK components of teachers with varying levels of experience. Ideally, as asserted by earlier research, the experienced teacher should have better and different PCK from a novice teacher [45,46,47]. This has also been recently corroborated by other researchers [12]. However, others also report that teaching experience had no significant impact on teachers' PCK [48,16].

### *Differences in PCK based on components' interactions*

*PCK interactions are based on training in education.*

On the other hand, there were differences in PCK, in terms of interactions between components, for training in education, major and teaching experience. Regardless of education training, both groups had interactions between teaching orientations and knowledge of instructional strategies. This indicates that both groups of teachers made decisions on instruction based on their orientations, which were didactic for both groups. However, only trained teachers showed an interaction between orientations and knowledge of science curricula. In this case, this positive interaction between OTTS and KSC, suggests, given the way the data was presented, that the more learner-centered a teacher was in their orientation the more likely it was that these teachers would favor the use of a vertical curriculum. This would make sense as trained teachers would have been exposed to the curriculum for teaching throughout their training and would have familiarized themselves with what students learn before SHS and what students will learn later in SHS and beyond in genetics. In fact, in the Ghanaian context, vertical curriculum, especially, the use of backward vertical curriculum is enshrined in common practice of trained teachers as teachers are encouraged to teach from the "known to the unknown" [49]. The senior high school biology teaching syllabus also advocates for teachers to

choose problems that allow students to apply the knowledge they acquired in the previous lesson [50].

*PCK interactions are based on teaching experience.*

Differences were observed in the PCK linkages of teachers according to their teaching experience. Firstly, teachers with “under 1 year” of teaching experience demonstrated one positive interaction between components, between OTTS & KSC. This interaction may point to the fact that novice teachers favor interactions between their own beliefs and the curriculum they implement. Similarly, Forbes and Davis [51] noted that novice teachers’ curriculum design efforts were influenced by their own views of science teaching and by features of their own distinct curricular settings. Meaning novice teachers do not simply teach what the curriculum stipulates but are actively making negotiations between their own beliefs and the curriculum. This emphasizes the dynamic nature of curriculum implementation and highlights the role of novice teachers’ personal beliefs and experiences in shaping their pedagogical practices. Understanding these interactions can serve as a platform upon which professional development programs catering to novice teachers’ PCK can be used to bridge the gap between teachers’ beliefs and curriculum goals.

Teachers with “1 to 5 years” of teaching experience, on the other hand, demonstrated two interactions, mediated by KIS and its interactions with OTTS and KSU. These comprise those with 1-3 years, termed early-stage by Graham et al. [16], and those with 4-5 years, considered late-stage by Graham et al. [16] or labelled as experienced by Sen et al. [52]. This group of teachers demonstrated more PCK connections than those who had less than a year of experience. What was particularly interesting to note was that both connections were mediated by KIS. Specifically, it suggests that this group of teachers was more interested in aligning their beliefs about genetics and their knowledge of students’ understanding with their instructional methods. This central role for instruction was not consistent as the years of experience increased.

For teachers with “6 to 10 years” of experience, it was rather the KSC that was mediating the connections. Nonetheless, this group also had one more connection than teachers with under 1 year of teaching experience. Specifically, these teachers had connections between KSC and OTTS, and KSC and KSU. In a mirror image of those teachers with “1 to 5 years” of experience, this group demonstrated the same connections to OTTS and KSU, but this time it wasn’t instruction that was center stage, it was rather the curriculum. This suggests that as teachers gain more experience, instructional knowledge gives way to knowledge of curriculum. Hence teachers with “6 to 10” years of experience are more concerned with making negotiations between what the curriculum says, and its relationship to their own beliefs of teaching genetics and students’ understanding of genetics. This reduction in focus of instruction with increasing experience has been noted by others. For example, Schachter et al. [53] in investigating the effect of teaching experience on language and literacy instruction noted that teacher experience was negatively associated with the amount of instruction provided by teachers. Earlier work like that of Mastrilli [54] also asserts that while teaching experience

may not have any effect on instructional strategies, sometimes it may even have a negative effect on instructional strategies.

An explanation for the focus on curricular knowledge with experience might be that these teachers become more familiar with the curriculum as they gain experience. Louws et al. [15] in assessing teachers’ self-articulated professional learning goals revealed that early to mid-career teachers were more interested in goals that aligned with instruction and curriculum and suggested that instruction and curriculum are central to teachers’ continuous development.

These first stages of teaching experience discussed so far fit perfectly into Fuller’s [55] stages of teachers’ concerns as they gain experience; first teachers are focused on themselves (OTTS) then they are concerned with instruction (KIS and may include KSC), and later they are concerned with the impact of their teaching on their students (KSU). This typifies the types of connections identified according to teaching experience. These findings add evidence to the role of teaching experience on some of these components and their interactions.

For teachers with more than 10 years of experience however, this study did not identify any linkages between PCK components. There seems to be a consensus, with multiple researchers, that at some point, teaching experience can have a negative impact on PCK. For example, Asl et al. [56] found that pedagogical content knowledge was highest for teachers with less than 10 years of experience and lowest among teachers with 21 to 30 years of experience. Dickson et al. [57] also identified that teachers with more than 10 years of experience are less student-centered and hence teacher-centered than those with less experience.

One explanation, as provided by Rabinowitz and Rosenbaum [58], is that teachers, as they gain more experience, become disillusioned and jaded. They consider that perhaps those with moderate levels of experience have acquired enough self-assurance and expertise to implement their desired teaching methods effectively while preserving the enthusiasm and vitality for teaching that, some more seasoned colleagues might lose over time.

## 5. Implications To Research And Practice

This study reinforces the view that PCK is best understood through component interactions, not in isolation. It highlights a lack of disparities within PCK components but substantial differences in their interactions. Moreover, it underscores the significance of education training, signifying its objective value to teachers’ professional knowledge. The study further corroborates existing research, indicating that while teaching experience can enhance PCK, excessive experience may yield detrimental effects.

## 6. Conclusion

This study explored the impact of training and teaching experience on Ghanaian SHS teachers’ pedagogical

content knowledge (PCK) in genetics, using Magnusson et al.'s [23] framework. It revealed no significant differences between individual PCK components, aligning with consensus that PCK is better understood through component interactions [6,17]. Differences emerge however, in component interactions based on teaching experience, training, and majors. Notably, training in education enhances PCK interactions, while excessive experience may hinder them. This suggests that continuous professional development is crucial for maintaining effective PCK, as shown by Mapulanga et al. [59], especially as teachers gain experience.

## Future Research

Future research may investigate how teachers of varying experience and training demonstrate their pedagogical content knowledge in the classroom. This will shed further light on the nature of their PCK in practice and exactly how experience and training come into play. Further, more work could be done on the perceptions and experiences of teachers with more than 10 years of teaching experience regarding teaching and learning activities. This may support or explain the findings of this study regarding the negative effect of more than 10 years of experience on PCK component interactions.

### Limitations of the study

While questionnaires offer a quick glimpse into teachers' alignment with PCK components, they can't capture the unique and individualized PCK observed in each teacher. They also don't illuminate actual classroom practices, as teachers might express preferences that don't necessarily reflect their real-world approach. Despite clarifying to teachers that there were no objectively correct choices, they may have opted for what seemed most fitting. However, in this cross-sectional survey, questionnaires enabled the assessment of numerous teachers simultaneously.

### Ethical Statement

The University of Cape Coast's Faculty of Science and Technology Education approved this study according to its ethical guidelines for research involving human participants.

### Statement on originality of work

Some of the data and analyses for this study were derived from an unpublished Doctoral thesis authored and defended by one of the co-authors [60]. The authors of this paper consider this work to be a valuable and distinctive addition to academic discussions.

### Disclosure statement

The present study was solely supported by personal resources without any external funding. Additionally, the authors declare no conflicts of interest in relation to this research endeavor.

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