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Research Article

Teacher Pedagogical Content Knowledge and Practical Skills Competence as Determinants of Students' Performance in Biology

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Abstract: The research examined the relationship between teacher pedagogical content knowledge and practical skills competence as factors influencing students' performance in Biology within the Abeokuta South Local Government Area of Ogun State. Employing a correlational research design, the study involved 240 respondents, specifically SSII biology students, who were selected through a multistage sampling technique. Data were gathered using the Teacher Pedagogical Content Knowledge and Competence in Practical Skills Rating Scale, which demonstrated reliability coefficients of 0.80 and 0.73, respectively. The analysis of the collected data utilized descriptive statistics and multiple regression techniques. The findings indicated a significant influence of the level of teacher pedagogical content knowledge and competence in practical skills on the academic performance of students. The findings also revealed that teachers' competence in practical skills has a positive effect on students' understanding of biological concepts and students' performance in biology. In light of these results, the study recommends that educators should im-prove their pedagogical content knowledge and practical skills competence to improve students' performance in Biology. Furthermore, teacher training programs should prioritize the development of robust content knowledge and practical skills in the field of Biology.

Keywords: biological concepts; comprehension; education; influence; outcome

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1. Introduction

Pedagogical Content Knowledge (PCK) serves as a theoretical framework that elucidates the pedagogical competencies of educators in relation to their instructional practices, thereby establishing a foundation for research into the enhancement of teachers' knowledge. The author delineated a program aimed at elucidating the essential elements of teaching and the processes through which these elements are cultivated in educational activities (Kim et al., 2018; Kleickmann et al., 2013; Neumann et al., 2019; Almonacid-Fierroet al., 2023). This framework encompasses a teacher's deep understanding of the subject matter they instruct, along with their ability to convey this knowledge in ways that are comprehensible to students. In the context of STEM (Science, Technology, Engineering, and Mathematics) education, it entails the capability to anticipate and address student misconceptions, design engaging learning experiences, and foster critical thinking and problem-solving skills (Filgona et al., 2020).

Given the pivotal role of teacher PCK in facilitating student learning outcomes in science disciplines, numerous researchers have explored this topic (Behling et al., 2022; Chan et al., 2019; Gess-Newsome et al., 2019; Park et al., 2020). Various methodologies have been employed to assess teacher PCK, including interviews with educators (Mapulanga et al., 2022; Suh & Park, 2017), analysis of written materials from both teachers and students (document analysis), classroom observations, and surveys directed at both teachers and students (Halim et al., 2014; Uner & Akkus, 2019). Additionally, Maseko and Khoza (2021) utilized a mixed-methods approach, incorporating questionnaires, interviews, and classroom observations to investigate teacher professional knowledge.

In the realm of science education, educators who possess robust PCK are adept at bridging the gap between abstract scientific concepts and the lived experiences of students (Magnusson et al., 1999; Gess-Newsome et al., 2019). They are skilled in presenting complex ideas in accessible ways, thereby fostering a more profound understanding of fundamental scientific principles. Moreover, involving students in authentic scientific activities through practical experiments, inquiry-driven learning, and the integration of real-life examples allows educators with a strong foundation in PCK to foster curiosity and a passion for discovery among learners. (Minner et al., 2010; Fraser, 2017). Proficient STEM educators recognize the diverse backgrounds, interests, and learning styles of their students (Killpack & Melón, 2016; Rosicka, 2016; Timms et al., 2018). With a deep understanding of PCK, they are able to customize their teaching approaches to meet the needs of all students, thereby ensuring equitable access to high-quality education for everyone (Karaman, 2012; Loughran et al., 2012; Sarkim, 2020). Ultimately, the PCK of educators is crucial in preparing students for the demands of the modern workforce and society. Educators possessing robust PCK provide students with specialized knowledge and skills pertinent to their disciplines, while simultaneously nurturing vital competencies such as critical thinking, collaboration, and adaptability. This approach empowers students to succeed in a progressively intricate and interconnected world. They cultivate the next generation of scientists, engineers, technologists, and mathematicians, equipping them with the necessary tools and mindset to tackle global challenges and drive innovation and progress (Elías et al., 2022).

Biology education holds a significant role in the field of scientific inquiry, offering students a deeper understanding of the intricate dynamics of life on Earth (Okenyi, 2013; Nurse, 2016; Ahmad et al., 2018). Central to the success of biology instruction is the concept of PCK, which merges content expertise with teaching proficiency. A key element of effective biology education is the development of a deep conceptual understanding of biological processes. Educators with extensive PCK can elucidate complex biological ideas in accessible terms, bridging the gap between theoretical frameworks and their practical implications (Mapulanga et al., 2022). Educators purposefully employ analogies, visual aids, and inquiry-based activities to enrich students' learning experiences, promoting a more profound understanding and retention of biological concepts. (Gholam, 2019; Darling-Hammond et al., 2020).

The core of biology is rooted in exploration, encouraging students to investigate, question, and discover the underlying mechanisms of life. Biology instructors with a robust PCK foundation advocate for inquiry-based teaching methods, guiding students through authentic scientific investigations (Alfieri et al., 2011; Attard et al., 2021). Educators motivate learners to participate in critical thinking and cultivate the investigative abilities necessary for scientific research by posing stimulating questions, facilitating interactive laboratory experiences, and promoting scientific discussions (Kennedy, 2013; Darling-Hammond et al., 2024). Additionally, encouraging interdisciplinary exploration and emphasizing the complex nature of scientific enquiry (Wagner et al., 2011; You, 2017; Kurup et al., 2021) broadens students' viewpoints, fostering a comprehensive understanding of the importance of biology in addressing global issues.

One crucial factor that may affect students' performance in the sciences is their proficiency in practical skills (Usman & Sabo, 2018). Therefore, to achieve the desired academic outcomes in practical subjects, the expertise of educators plays a fundamental role. Competence encompasses a broad spectrum of abilities that extend beyond the teacher's mere knowledge of the subject (Canuto et al., 2024). Teaching competence includes the knowledge, skills, values, attitudes, and behaviors that educators demonstrate to improve their effectiveness in the classroom. It is essential for educators to pursue high standards, which involves pedagogical knowledge, motivation, experiences, interests, professional development, and inherent abilities (Nessipbayeva, 2012).

Bachmann (2018) asserts that teachers must excel in their roles for effective teaching and learning to occur. To identify these competencies, it is necessary to examine them within the framework of teaching practices. Educators' abilities should be connected to their academic and instructional experiences, professional development, student engagement, and assessment (Rodrigues et al., 2021). Professional competencies can be categorized into two types: academic and pedagogical. Academic competence pertains to a teacher's subject knowledge, while pedagogical competence relates to the methods employed to teach a subject, following principles such as progressing from the known to the unknown, from concrete to abstract, and from simple to complex (Murkatik et al., 2020). A teacher's effectiveness in the classroom is largely determined by their ability to plan and implement teaching practices. The

improvement of students' achievements in biology is significantly dependent on the practical skills competence of their teachers.

This competence enhances students' understanding of theoretical concepts and offers them a more profound insight into biological principles. The integration of practical skills within biology education seeks to foster a more comprehensive and effective learning environment (Alafiatayo et al., 2016). The exhibition of exemplary and effective teaching abilities in biology and other scientific fields is significantly dependent on practical skills (Aslan, 2015; Amoah et al., 2018).

Currently, there is a paucity of research focused on clarifying the relationship between teacher PCK, their competence in practical skills, and the academic success of biology students. Although numerous studies have investigated various dimensions of teachers' subject matter expertise and skills, there is a notable lack of literature addressing the connection between PCK, practical skills competence, and students' academic performance in biology. This knowledge gap could provide critical insights for educators, researchers, and educational institutions concerning the factors influencing the quality of biology education. A thorough understanding of teacher PCK and their proficiency in practical skills is vital for formulating informed pedagogical strategies that empower educators to create engaging and effective learning experiences, thereby laying a solid foundation for the sustained learning and future academic success of biology students. Hence, this research was conducted to examine the relationship between teacher PCK and practical skills competence as factors influencing students' performance in Biology within the Abeokuta South Local Government Area of Ogun State.

The research questions are the following:

1. What is the level of teacher PCK, practical skills competence and academic performance in Biology among secondary school students?
2. To what extent do teacher practical skills affect students' understanding of biological concepts?
3. What is the impact of teacher PCK and practical skills competence on students' performance in Biology?

2. Materials and Methods

This study employed a correlation research design, which is characterized by the collection of data following observable changes, where the variables of interest are not subject to manipulation. The study's population consisted of all Senior Secondary School Two (SSSII) Biology students within the Abeokuta South Local Government Area of Ogun State. To select the target samples, a Multistage Random Sampling Technique was implemented. Initially, a purposive sampling method was utilized to identify 12 secondary schools in the specified area. Subsequently, a systematic sampling approach was employed to choose 20 students from each SSS II class in the selected schools, resulting in a total of 240 respondents for the study. Ethical approval was granted by the school vice principal, academics, before the initiation of data collection. Informed consent was obtained from the students, guaranteeing that participation was completely voluntary. Students were assured that their responses would remain confidential and anonymous, utilized exclusively for research purpose. To gather data, the researcher developed the "Teacher PCK and Competence in Practical Skills Rating Scale," which comprised four sections. The first section collected demographic information, including gender, school type, and age (Table 1).

Table 1. Socio-demographic characteristics of the respondents.

Variables	Frequency	Percentage (%)
Gender of the Respondents		
Male	72	30.0
Female	168	70.0
Age of the Respondents		
12-14 years	103	42.9
15-16 year	116	48.3
17 years and above	21	8.75

School Type		
Public	140	58.3
Private	100	41.7

Section B focused on students' perceptions of their teacher PCK. Section C examined students' views on how teachers' competence in practical skills affects their academic performance in Biology, while Section D explored students' perceptions regarding the influence of teachers' practical skills on their understanding of biological concepts. The rating scale utilized a four-point Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree). The instrument underwent face and content validation, with two experts reviewing it to eliminate any ambiguities. A pilot test was conducted with a sample of 20 students, who were not part of the targeted sample but belonged to the broader population. The reliability of the instrument was established using the Cronbach Alpha method. The reliability coefficients of 0.80 and 0.73 indicate that the instruments employed were dependable for application. The researcher, in collaboration with the headteacher of academics at each chosen secondary school, utilized a direct method to administer and gather the instruments. The ratings obtained from each response on the instruments were considered as the data pertaining to each variable for the respondents. To summarize the socio-demographic characteristics of the respondents, descriptive statistics, including frequency and percentage distributions, were applied, while Pearson Product Moment Correlation was utilized for regression analysis at a significance level of 0.05.

3. Results

3.1. What is the level of teacher pedagogical content, practical skills competence and academic performance in Biology?

Table 2 illustrates the levels of teacher PCK, teachers' competence in practical skills, and students' academic performance in Biology, differentiated by gender. The data encompasses mean scores and standard deviations for both male and female students, reflecting various levels of teacher PCK and practical skills competence.

Table 2. Level of teacher PCK, practical skills competence, and academic performance in Biology.

	Indicator	**Male (n= 72)**		**Female (n = 168)**	
		Mean	Std.D	Mean	Std.D
Level of Teacher PCK	Low	23.885	9.177	20.669	10.254
	Medium	37.561	8.650	38.955	8.727
	High	49.905	10.476	52.546	11.190
Level of Teacher Competence in Practical Skills	Low	17.302	8.012	18.213	9.011
	Medium	18.452	9.001	18.711	9.820
	High	23.452	10.234	24.021	11.212
Academic Performance in Biology		67.698	10.459	66.045	11.928

The results showed low level of students' perception of their teacher's PCK with a mean of 23.88, a standard deviation of 9.177 for male and 20.669 and 10.254 for female. Also, 38.955 reflected the mean with a standard deviation of 8.727 for female compared to male students with 37.561, a standard deviation of 8.650. This implies that female students indicated that their teacher demonstrated a higher level of PCK than the male students. In addition, the result revealed the level of teachers' competence in practical skills: It showed that Biology teachers in the study area demonstrated high level of competence in practical skills. This is evidenced in their respective mean scores and standard deviation, female students indicated (mean = 24.021, SD = 11.212) compared with male students (mean = 23.45, SD = 10.23) respectively. With the evidence in the result on the level of teacher PCK and competence in practical skills, there is a significant influence of the level of teacher PCK and competence in practical skills on the academic performance of students as male students showing high mean value (mean = 67.698, SD = 10.459) over female students with a mean score of 66.045 and SD of 11.928 respectively. The general observation from the findings

showed that the level of teacher PCK and competence in practical skills significantly influenced the academic performance of the students in biology.

3.2. To what extent does teachers' competence in practical skills affect students' understanding of biological concepts?

The results of the regression and ANOVA of students' competence skills in practical revealed multiple correlation coefficients of 0.516 between the combined predictor variable and students' academic performance is presented in the table below.

Table 3. Regression summaries and ANOVA on the impact of teachers' competence in practical skills on students' understanding of biological concepts.

Multiple R = .516[a], R. Square = .379, Adjusted R Square =.368, Standard Error = 5.244						
Analysis of Variance						
Source of Variance	**SS**	**Df**	**MS**	**F**	**Sig.**	**Remark**
Regression	2641.011	1	2641.011	11.474	.000[b]	Sign. (P<0.05
Residual	55934.065	238	230.181			
Total	58575.076	239				

The adjusted R2, which estimates the variance accounted for in the combined predictor variables to the criterion variable measure was 0.368 which translates to 36.8% variance in students' understanding of biological concepts is accounted for by teachers' competence in practical skills. The table also shows the regression equation (F (1, 238) =11.474, p = 0.000), this implies that the teachers' competence in practical skills is effective in influencing students' understanding of biological concepts since it is significant at $p < 0.05$. In addition, analysis of the coefficient table shows, that teachers' competence in practical skills has a t-statistic value t= 12.149 with P= 0.000. This indicates that the two variables are statistically significant because P= 0.000, P< 0.05. The non-standardized coefficient measures the extent to which the independent variable can predict the dependent variable. The findings revealed that teachers' competence in practical skills has a positive effect on students' understanding of biological concepts.

3.3. What is the impact of teacher PCK and practical skills competence on students' performance in Biology?

Findings revealed a positive impact of teacher PCK and practical skills competence on students' performance in biology (Table 4).

Table 4. Regression Summaries and ANOVA of impact of teacher PCK and practical skills competence on students' performance in Biology.

R = .484,	**R Square = .258,**	**Adjusted R Square = .255,**		**Std. Error = 11.829**	
Source of Variation	Sum of Squares	Df	Mean Square	F	Sig.
Regression	1704.456	2	852.228	20.487	.000[b]
Residual	9859.091	237	41.599		
Total	11563.547	239			

The multiple correlation coefficients (R) of the combined predictor variable with students' academic performance was 0.484. The adjusted R2, which estimates the variance accounted for in the combined predictor variables to the criterion variable measure was 0.255 which translates to 25.5% variance in students' academic performance in biology is attributed to teacher PCK and practical skills competence. Result also revealed the regression equation ($F_{(2, 237)}$ =20.487, p = 0.010), this implies that the combination of the predictor variable is effective in influencing students' academic performance in biology since it is significant at $p < 0.05$ which indicates that the obtained regression resulting from teacher PCK and practical skills competence allow reliable prediction of students' performance in biology. It can be inferred from the results above that teacher PCK and practical skills competence had a significant impact on student performance in biology.

4. Discussion

The investigation into the first research question revealed that female students perceived a moderate level of PCK exhibited by their teachers, in contrast to their male peers. This infers that the quality of learning female students received from their teachers was moderate, while male students claimed to receive low quality learning from their teachers. Female assertion of their teacher PCK correlates with the findings of Halim, Abdullah, and Meerah (2014) and Mapulanga, Nshogoza, and Ameyaw (2023). Meanwhile, male students' perception of their teacher PCK is in line with the report of Sofianidis and Kallery (2021). Busaka, Kitta, and Umugiraneza (2022) indicated that there are no significant differences in the perceptions of PCK between male and female students. Likewise, Choi, and Reynolds (2020) reported no substantial variations in the PCK scores of teachers based on the gender of their students. However, further investigations are required to understand the reasons behind the differences in how male and female students perceive their teachers' pedagogical knowledge. Regarding the second research question, the results indicated that teachers' proficiency in practical skills positively influenced students' understanding of biological concepts. This finding is consistent with the work of Fadzil and Saat (2020), Ihejiamaizu, Nyenke, and Neji (2020), who highlighted the critical role of teachers' instructional effectiveness in enhancing students' comprehension of Biology and understanding biological concepts. Additionally, Tuyishime and Tukahabwa (2022) contended that students could attain a satisfactory understanding of concepts through theoretical explanations and demonstrations alone, thereby questioning the assertion that teacher proficiency in practical skills is a crucial determinant of students' understanding of biological concepts. Studies had established that biology practical lessons enhanced active interaction and retention capabilities (Ude & Ebuoh, 2018; Abidoye & Omotayo, 2023; Tuyishime & Tukahabwa, 2023). Effective practical work fosters students' cognitive competence (Nneji et al., 2024), The results indicating that both teacher PCK and their practical skills significantly affect students' performance in biology are in agreement with the conclusion of Galicia and Kao (2024), who

noted that hands-on tactile approaches facilitated by skilled teachers enable students to better understand complex biological concepts. Furthermore, enhancing teachers' practical skills in biology can positively influence students' attitudes toward the subject, as suggested by Adeyemi and Awolere (2016), who emphasized the value of practical activities in making teaching more relatable compared to abstract or theoretical methods. The way in which concepts are presented to students is crucial in cultivating the appropriate understanding.

5. Conclusions

This study highlights the critical significance of both teacher PCK and competence in practical skills in enhancing biology education. Research indicates that the academic success of students in biology is significantly impacted by teacher PCK and their proficiency in executing practical activities within the classroom. This underscores the critical importance of PCK in the realm of biology education. Educators with robust PCK are equipped to enhance students' conceptual understanding, encourage inquiry-based learning, rectify misconceptions, and advance scientific literacy. As comprehension of biology evolves, it is vital to invest in the enhancement of teacher PCK to cultivate the future generation of biologists, environmentalists, healthcare professionals, and informed citizens ready to confront future challenges.

PCK is essential for the progress of STEM education. Teachers who exhibit strong PCK are not only knowledgeable in their subject areas but also adept practitioners capable of motivating and empowering future STEM leaders. Therefore, investing in the development of teacher PCK is fundamental to achieving excellence and equity in STEM education, which in turn fosters innovation and societal advancement.

Furthermore, it is crucial for future research to investigate the particular elements that contribute to gender-based disparities in students' perceptions of their educational experiences. By understanding these factors, educators can gain insights into how different genders engage with learning materials and classroom dynamics, which can inform the development of more tailored and inclusive teaching approaches. It is essential for educators to receive continuous training in these domains to foster better learning outcomes for students.

Additionally, achieving optimal educational results will require the establishment of an equitable and inclusive learning environment that acknowledges the diverse perspectives of

all students, regardless of gender. This proactive approach will not only enhance the effectiveness of teaching strategies but also ensure that all students feel valued and supported in their learning journeys.

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