# Teacher's Pedagogical Content Knowledge as Predictor of Students' Numerical Proficiency in Solving Physics Problems in Secondary schools

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***Abstract***
*The research examined the relationship between teachers' pedagogical content knowledge and students' abilities in solving numerical problems in physics at the secondary school level. The study was organized around two specific objectives, two research questions, and two hypotheses. A correlational survey research design was employed for this study. Conducted in the Onitsha Education Zone of Anambra State, the study included a sample of 61 physics teachers (4 males and 57 females) and 6,348 SS2 students from 32 public secondary schools. A total of 220 participants were chosen through a multi-stage sampling technique, which comprised 20 teachers (4 male and 16 female) and 200 physics students. Data were gathered using two validated tools: the Physics Teachers' Pedagogical Content Knowledge Rating Scale (PTPCKRS) and the Physics Students' Numerical Proficiency Test (PSNPT), both of which were validated by three experts. The reliability of the PTPCKRS was evaluated using the Cronbach alpha formula, resulting in a reliability score of 0.73. In contrast, the reliability of the PSNPT was determined through scorer reliability, employing the Kendall coefficient of concordance, which yielded a reliability coefficient of 0.71. The researcher, with the support of five research assistants, conducted the tests. Data analysis was carried out using simple linear regression to address the research question and one-way analysis of variance (ANOVA) for the hypothesis. The results indicated that teachers' pedagogical content knowledge is a significant predictor of students' numerical proficiency in solving physics problems. Furthermore, the coefficient of determination (R square) of 0.406 indicate that teachers' pedagogical content knowledge accounts for 40.6% of the variance in students' numerical proficiency in this area. Additionally, the study demonstrated that both male and female teachers' pedagogical content knowledge serves as a predictor of students' numerical proficiency in solving physics problems. Therefore, it was recommended that teacher training institutions prioritize the effective acquisition and mastery of content knowledge and suitable pedagogical strategies for all prospective educators irrespective of their gender.*

***Key words: Pedagogical Content Knowledge, numerical proficiency, problem solving, gender and teacher***

## Introduction

Despite the significant roles, benefits, and widespread recognition of physics in various domains of human activity and national progress, student performance, particularly in the numerical components of physics, remains unsatisfactory. This is highlighted in the reports from the Chief Examiners of the West African Examination Council (WAEC, 2020 & 2021), which identified several factors contributing to students' difficulties in solving physics problems. Key issues include insufficient mathematical skills, ineffective instructional methods, or a combination of both (Amasuomo & Ntibi, 2017; Muriithi, 2018). Consequently, it appears that enhancing students' performance, particularly in numerical skills, is likely to occur when they are instructed by effective teachers who possess not only pedagogical expertise and subject matter knowledge but also a strong understanding of pedagogical content knowledge. In light of this, numerous studies have been conducted focusing on students' numerical proficiency in physics, proposing strategies to enhance their problem-solving abilities, including the necessity for teachers to have robust pedagogical content knowledge.

Pedagogical content knowledge (PCK) is a unique form of knowledge that is specific to educators. It involves the integration of pedagogical knowledge—understanding how to teach—with subject matter knowledge —understanding the content being taught. As noted by Igi Global Publishers (2022), PCK represents the intersection of a teacher's content knowledge and their pedagogical knowledge regarding teaching and learning. The authors further elaborate that a robust PCK allows educators to select suitable instructional strategies that are effectively structured to convey subject content. For instance, a physics teacher may possess extensive knowledge of physics yet lack pedagogical content knowledge. Loughran, Berry, and Mulhall (2012) describe PCK as an academic construct that highlights the complexity of teaching, emphasizing that it involves more than merely delivering subject-specific information and that learning extends beyond rote memorization for future recitation. Koehler and Mishra (2017) define pedagogical content knowledge as the amalgamation of teachers' expertise in their subject area with their pedagogical understanding. They further contend that PCK includes essential elements of teaching, learning, curriculum design, assessment, and reporting, as well as the conditions that promote learning and the interrelationships among pedagogy, curriculum, and assessment.

In this study, Pedagogical Content Knowledge (PCK) is defined as the intersection of physics content knowledge and the pedagogical skills of physics teachers, aimed at enhancing students' numerical abilities in solving physics problems. Loughran, Berry and Mulhall (2012) emphasized that PCK is a unique competency characterized by significant variations influenced by factors such as the teaching environment, subject matter, and the teacher's experience, rather than being a uniform trait shared by all educators in a specific discipline. This indicates that while some teachers may exhibit similar PCK, others may demonstrate distinct differences; nonetheless, it remains a crucial element of teachers' professional expertise. Essentially, the knowledge acquired by physics teacher is organized from a pedagogical perspective and serves as a basis for facilitating student comprehension of the subject matter. It is important to highlight that the accumulation of pedagogical content knowledge significantly aids physics teachers in deepening their understanding of concepts and effectively evaluating students' learning outcomes, including their numerical proficiency.

Numerical proficiency in physics encompasses the ability to tackle mathematically oriented problems, which is vital for elucidating theoretical concepts within the field. This skill set includes both mathematical and computational competencies that enable students to grasp the interconnections among various physics principles, thereby enhancing their problem-solving approaches. As noted by Skills Panorama (2020), numerical proficiency entails the capacity to access, apply, interpret, and convey mathematical information and concepts, which is essential for navigating the mathematical challenges faced in different facets of adult life. Zewdie (2014) emphasized that the ability to resolve complex issues is a fundamental skill for individuals in today's fast-evolving technological landscape. Given the quantitative essence of physics, it encourages students to distill problems through calculations that may be either memorized or sourced externally (Beiser, Mahajan & Choudhury, 2011). Students who excel in physics are those capable of transforming intricate physics equations into more manageable forms, thus effectively solving numerical challenges (Beiser, Mahajan & Choudhury, 2011). The authors further argue that a robust comprehension of core physics concepts, combined with the ability to apply this understanding to complex formulas, significantly enhances students' problem-solving capabilities in the domain of physics.

Problem-solving is widely acknowledged as a vital factor influencing academic achievement in scientific disciplines, particularly in Physics. This challenge arises from students' tendency to memorize solutions presented by their teachers rather than developing a genuine understanding of problem-solving techniques, which is characteristic of traditional pedagogical approaches. Research has shown that a significant number of Physics educators believe that students entering the subject often lack adequate preparation for performing calculations (Frederick & Joan, 2010). Furthermore, studies suggest that while students may excel in solving standard quantitative Physics problems, they frequently do not possess a robust understanding of the essential conceptual or qualitative aspects of the field (Tenzin, 2019). This situation underscores the reality that students often acquire computational skills through memorization, without a comprehensive understanding of the underlying principles that inform their solutions. Additionally, it is widely recognized in Physics education that students often substitute values in equations without fully grasping when to assign a parameter a positive, negative, or zero value.

The numerical components of physics often induce anxiety in students. The mere mention of the subject can lead to a tendency to evade it, primarily due to its dependence on mathematical principles. Only a limited number of students who tackle these difficulties and succeed are regarded as leaders in the discipline. This perspective, however, is fundamentally misguided, as physics can be made accessible to all students when effectively taught by a skilled educator. According to Callahan, Cannon, Chesick, Mackin, Mandel, and Wennin (2011), achieving excellence in high school physics, which encompasses strong numerical skills in problem-solving, is significantly influenced by the teacher's role. In the absence of well-qualified educators, the potential for excellence in high school physics diminishes.

It is essential to investigate the connection between teachers' pedagogical content knowledge (PCK) and students' numerical skills. Research conducted by Lange, Kleickmann, and Möller (2012) demonstrated a significant correlation between teachers' PCK and student performance in elementary science, even after accounting for various student- and teacher-related factors. Conversely, Odumosu, Olisama, and Areelu (2018) reported that teachers' pedagogical knowledge did not significantly impact students' performance on algebraic achievement tests. Additionally, a study by Danisman and Tanisli (2017) examined the PCK of mathematics teachers regarding probability in Turkey, revealing that these secondary school teachers possessed inadequate PCK in this area, with their beliefs being the most influential factor affecting their PCK. Notably, neither of these studies specifically addressed students' numerical abilities. To the best of the researcher's knowledge, there has been no previous research exploring the relationship between teachers' pedagogical content knowledge and students' numerical understanding. Therefore, this study aims to investigate the predictive influence of teachers' PCK on students' numerical proficiency in solving physics problems, thereby addressing existing gaps in the literature. Furthermore, there remains an ongoing debate regarding whether the predictive influence of teachers's PCK, as moderated by teacher's affects students' numerical proficiency in solving physics problems.

The concept of gender as a social construct has garnered significant interest among researchers in the field of science education, especially in physics. The World Health Organization (2019) defines gender as the socially constructed characteristics that differentiate men from women. This definition suggests that gender encompasses an individual's personal identification with "maleness" or "femaleness," independent of their biological sex. In this study, gender is viewed as a social characteristic linked to male and female physics educators, which may or may not influence students' numerical proficiency when solving physics-related problems.

The origins of gender disparities in educational outcomes have been extensively researched and debated. In this context, Ibe, Nworgu, and Anyaegbunam (2016) discovered that the gender of teachers had an impact on students' performance in Biology. Conversely, Muriithi (2018) concluded that gender does not play a role in influencing students' academic success. Additionally, Ezema (2016) indicated that there is no significant difference in how teachers' gender affects students' performance. Given these conflicting findings, it is essential to conduct further research to ascertain whether the predictive influence of teachers's PCK, as moderated by teacher gender ,affects students' numerical skills in solving physics problems.

## Research Questions

In accordance with the objectives of the study, the subsequent research question directed the investigation:

What is the predictive power of teacher's pedagogical content knowledge on students' numerical proficiency in solving physics problems?

What is the predictive power of teacher's pedagogical content knowledge on students' numerical proficiency in solving physics problems as moderated by teacher's gender?

## Hypotheses

Based on the purpose of the study, the following hypothesis was formulated

**$Ho_1$:** Physics teacher's pedagogical content knowledge does not significantly predict students' numerical proficiency in solving physics problems.

**$Ho_2$**: Physics teacher's pedagogical content knowledge does not significantly predict students' numerical proficiency in solving physics problems as moderated by teacher's gender.

## Method

The research framework employed in this study is defined by a correlational research design. As noted by Nworgu (2015), the main aim of a correlational study is to clarify the relationship between two or more variables. This design is particularly suitable for the current investigation, which seeks to assess the predictive capacity of pedagogical content knowledge in relation to students' numerical abilities when solving physics problems. The research is geographically focused on the Onitsha education zone in Anambra State, encompassing three local government areas: Onitsha North, Onitsha South, and Ogbaru. This educational zone comprises thirty-two public secondary schools, with a distribution of sixteen in Onitsha North, six in Onitsha South, and ten in Ogbaru. The choice of this area is informed by its role as a commercial center, where many teachers are also involved in business pursuits, which often detracts from their focus on professional skills, including pedagogical content knowledge, in their teaching practices.

The study's population includes 61 physics educators (4 male and 57 female) and 6,348 SS2 students from all 32 public secondary schools within the Onitsha education zone. The research sample consists of 220 participants, which includes 20 physics teachers (4 male and 16 female) and 200 physics students, all of whom were randomly selected from 20 different schools.

Two assessment instruments were utilized for data collection: the Physics Teachers' Pedagogical Content Knowledge Rating Scale

(PTPCKRS) and the Physics Students' Numerical Proficiency Test (PSNPT). These tools were carefully crafted by the researcher to meet the specific aims of the study, informed by empirical research. The PTPCKRS was derived from the work of Aksu, Metin, and Konyal (2014), who created a pedagogical content knowledge (PCK) scale intended for pre-service teachers. The original version comprised 24 items and was based on a five-point scale ranging from strongly agree to strongly disagree, including an undecided option. However, during the adaptation process, the scale was modified to a four-point format by eliminating the undecided option. Additionally, certain items were revised; for instance, references to "lesson" were changed to "physics lesson." Item 21, which stated, “I can select appropriate teaching methods for standard,” was rephrased to, “I can select appropriate teaching methods for each class.” Furthermore, item 6, which stated, “I can consist a usable platform during lessons,” was removed due to its potential ambiguity for raters. Consequently, the final version of the instrument retained 24 items, with a maximum score of 96 and a minimum score of 24.

In contrast, the PSNPT comprises twenty (20) questions focused on calculations, designed to evaluate students' numerical skills in addressing physics problems. The validation of these assessment tools were carried out by three specialists: one from the Measurement and Evaluation unit and two from the Physics Education unit, all associated with the Faculty of Education at the University of Nigeria, Nsukka (UNN). The reliability of the PTPCKRS was determined using the Cronbach alpha formula, resulting in a reliability coefficient of 0.73. This formula was chosen due to the non-dichotomous nature of the scoring for the instruments. For the PSNPT, reliability was evaluated through scorer reliability, employing the Kendall coefficient of concordance. This method was appropriate given that three raters assessed the responses from both teachers and students. The reliability coefficient calculated for the PSNPT was 0.71. The instruments were administered and collected in a timely manner, and the resulting data were analyzed using simple linear regression for the research questions and analysis of variance for the hypotheses.

## Results

The results of the study are presented in the tables below

**Research Question 1**

What is the predictive power of teacher's pedagogical content knowledge on students' numerical proficiency in solving physics problems?

**Table 1**

***Regression coefficient of the predictive power of teacher's pedagogical content knowledge on students' numerical proficiency in solving physics problems***

Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .637[a] | .406 | .373 | 16.96567 |

a. Predictors: (Constant), PTPCK

**Table 1** presents a regression coefficient of R equal to 0.637, indicating that a teacher's pedagogical content knowledge serves as a strong predictor of students' ability to solve physics problems numerically. Furthermore, the coefficient of determination (R squared) of 0.406 demonstrates that this pedagogical knowledge accounts for 40.6% of the variance in students' numerical proficiency in physics problem-solving.

**Hypothesis 1**: Physics teacher's pedagogical content knowledge does not significantly predict students' numerical proficiency in solving physics problems.

**Table 2**
***Analysis of variance (ANOVA) on predictive power of teacher's* pedagogical content knowledge *on students' numerical proficiency in solving physics problems.***

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 3542.737 | 1 | 3542.737 | 12.308 | .003[b] |
| | Residual | 5181.013 | 18 | 287.834 | | |
| | Total | 8723.750 | 19 | | | |

ANOVA[a]
a. Dependent Variable: NP
b. Predictors: (Constant), PTPCK

Table 2 presents the results indicating F(1, 18) = 12.308, p = 0.003, which is less than 0.05. This finding suggests that the null hypothesis is rejected in favor of the alternative hypothesis. Consequently, the pedagogical content knowledge of physics teachers serves as a significant predictor of students' ability to solve numerical physics problems.

**Research Question 2**
What is the predictive power of teacher's pedagogical content knowledge on students' numerical proficiency in solving physics problems as moderated by teacher's gender?

**Table 3**
**Regression coefficient of the predictive power of teacher's pedagogical content knowledge on students' numerical proficiency in solving physics problems as moderated by teacher's gender**

| S/N | Gender | N | R | $R^2$ | t-value | p-value | Decision |
|---|---|---|---|---|---|---|---|
| 1 | Male Teachers | 4 | 0.84 | 0.71 | 5.79 | 0.030 | S |
| 2 | Female Teachers | 16 | 0.79 | 0.63 | 24.030 | 0.000 | S |

Table 3 indicates that gender serves as a moderating factor in the relationship between teachers' pedagogical content knowledge and students' numerical proficiency in solving physics problems, with a moderation effect of 0.05. Furthermore, a coefficient of determination of 0.08 (0.71 – 0.63) suggests that gender moderates this relationship by 5%. This implies that the pedagogical content knowledge of both male and female teachers is predictive of students' numerical proficiency in addressing physics problems.

**Hypothesis 2**: Physics teacher's pedagogical content knowledge does not significantly predict students' numerical proficiency in solving physics problems as moderated by teacher's gender.

**Table 4**
**Regression coefficient of the predictive power of teacher's pedagogical content knowledge on students' numerical proficiency in solving physics problems as moderated by teacher's gender**

| S/N | Experience | N | R | $R^2$ | t-value | p-value | Decision |
|---|---|---|---|---|---|---|---|
| 1 | Male | 4 | 0.84 | 0.71 | 5.79 | 0.030 | S |
| 2 | Female | 16 | 0.79 | 0.63 | 24.030 | 0.000 | S |

Table 4 presents the findings for male teachers, indicating F(1, 15) = 5.79, p = 0.030, which is less than the 0.05 significance threshold. This result suggests that the pedagogical content knowledge of male teachers is a significant predictor of students' numerical proficiency in solving physics problems. In a similar vein, for female teachers, the analysis yields F(1, 3) = 24.030, p = 0.99, also below the 0.05 significance level. This implies that the pedagogical content knowledge of female teachers likewise significantly influences students' numerical proficiency in physics problem-solving. Therefore, it can be concluded that the gender of physics teachers plays a significant moderating role in the relationship between pedagogical content knowledge and students' numerical proficiency in addressing physics problems.

**Discussion**
Findings revealed that teacher's pedagogical content knowledge (PCK) is a high predictor of students' numerical proficiency in solving physics problems, meaning that teachers' pedagogical content knowledge is a significant

predictor of students' numerical proficiency in solving physics problems. The finding could be attributable to the blending of pedagogical skills and content knowledge by the teacher. This means that teachers with good PCK link pedagogical skills and content knowledge while teaching thereby making teaching and learning meaningful. Such teacher(s) use(s) both the knowledge of subject matter/curriculum and blend them with good pedagogy, assessment practices coupled with knowledge of the learners in bringing about meaningful learning. Thus, in solving mathematical/numerical problems, the teachers bring her/his knowledge, pedagogical skills and good assessment practices to bear making learning of numerical problems easier for the learners. The findings of the study agree with the findings of Langα Kleickmann and Möller (2012) who found that pedagogical content knowledge (PCK) in the content area "states of matter and changes of state" contribute to gains in elementary students' understanding of related concepts in Germany. The result further showed that teachers' PCK was significantly related to student achievement in elementary science after controlling for key student- and teacher-level covariates. Also, the results of Lucenario, Yangco, Punzalan and Espinosa (2016) who investigated the effectiveness of Pedagogical Content Knowledge-Guided Lesson Study (PCKLS) as an intervention to develop PCK competencies among teachers and consequently found at PCKLS enhanced students' achievement in terms of conceptual understanding and problem-solving skills in Chemistry in the Philippines.

However, findings of Odumosu, Olisama and Areelu (2018) who investigated the influence of teachers' content and pedagogical content knowledge on students' achievement in algebra revealed that students were not affected by Teachers' Pedagogical Content Knowledge in algebraic achievement test. This finding did not corroborate with findings of the present study. Also, Josiah and Oluwatoyin (2017) study that investigated teachers' pedagogical content knowledge as a determinant of students' academic performance in secondary schools in Edo south senatorial district of Nigeria found that teacher quality and academic qualification had no significant influence on students' academic performance, thus disagreeing with the findings of the present study. These disagreements in findings could be attributed to how the instruments were scored. The instruments must be scored in equality order for linear correlation to be felt.

In addition, findings from this study revealed that gender moderate teachers' pedagogical content knowledge on students' numerical proficiency in solving physics problems by 5%. Thus, both male and female teachers' pedagogical content knowledge predict students' numerical proficiency in solving physics problems. This finding is in order because physics and indeed all sciences can be learnt and taught by both gender if the enabling environment is provided. This means that if a male or female teacher possesses the right pedagogical content knowledge, such teacher will definitely use that to impact sound numerical problem solving skills to the students. Thus it should not be discriminated by gender. However, findings with respect to gender differs. For example, Ibe, Nworgu and Anyaegbunam (2016) found that teachers' gender influenced students' achievement in Biology. Similarly, Ajaja and Eravwoke (2013) found that there is a significant higher classroom behaviour score of male teachers over the females. Also, Ebiringa (2012) found that gender has a significant influence on the competencies possessed by the teachers. But on the other hand, Uzuegbu, Mbadiwe, and Anulobi (2013) found out that teachers' gender has no significant influence on students' interest and performance. Ezema (2016) revealed that there is no significant difference in the influence of teachers' gender on students' performance. In line with this, Muriithi (2018) found that gender is not a factor in influencing learner academic achievement. These differences could be attributed to the nature of study investigated. The present study investigated the moderating influence of gender on students' numerical proficiency, while all these studies were directly on achievement and this is the gap that the present study intends to fill.

**Conclusion**

The results and ensuing discourse prompted the researchers to conclude that a teacher's pedagogical content knowledge is a vital factor influencing students' proficiency in solving physics problems that incorporate numerical concepts. Also teachers' gender moderates the predictability of teachers' pedagogical content knowledge on students' numerical proficiency in solving physics problems.

**Recommendation**

Based on findings of the study, it is recommended that in-service training should be provided to the serving teachers to keep them abreast with current trends on pedagogical skills, content knowledge and pedagogical content knowledge such as ICT driven pedagogy among others. Additionally, during teacher training in physics, efforts should be made by ensuring that female would- be-teachers are carried along while teaching especially mathematically inclined topics and no gender suggestive language should be used. Also, special incentives should be provided for female students who take career in physics education to encourage more of them in the field.

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