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

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Abstract
The study investigated the correlation between teachers' content knowledge and students' proficiency in numerical problem-solving within the realm of physics at the secondary school level. The research was structured around a defined objective, a central research question, and a formulated hypothesis. A correlational survey research design was utilized for this investigation. Conducted in the Onitsha Education Zone of Anambra State, the research encompassed a sample of 61 physics teachers (4 males and 57 females) and 6,348 SS2 students from 32 public secondary schools during the 2022/2023 academic year. A total of 220 participants were selected through a multi-stage sampling method, which included 20 teachers (4 male and 16 female) and 200 physics students. Data collection was carried out using two validated instruments: the Physics Teachers' Content Knowledge Test (PTCKT) and the Physics Students' Numerical Proficiency Test (PSNPT), both of which received validation from three experts. The reliability of the assessments was determined using the Kendall coefficient of concordance, resulting in reliability coefficients of 0.80 for the PTCKT and 0.81 for the PSNPT. The researcher, assisted by five research aides, administered the tests. Data analysis was performed using simple linear regression for the research question and one-way analysis of variance (ANOVA) for the hypothesis. The findings revealed that teachers' characteristics, particularly their content knowledge (R2=21.3%), are significant predictors of students' numerical proficiency in solving physics-related problems. Consequently, it is recommended that teacher training institutions emphasize the proper acquisition and mastery of content knowledge for all future educators before their graduation.

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

Introduction

In spite of the important roles, advantages, needs and popularity of physics in all spheres of human endeavour and national development, the performance of students especially in numerical aspects of physics is not encouraging. This is evidenced in the report of WAEC Chief Examiners (West African Examination Council, WAEC, 2020 & 2021) that there are different factors for students' failure in solving Physics problems. Among these is students' poor background in mathematical aspects of physics (Olanrewaju, 2015). This could be evidenced in the fact that most of the physics teachers have poor background of mathematics, thus, they only teach the introductory part of the topics (Apata, 2013; Akanbi, Omosewo & Nase, 2018 & Muriithi, 2018). To this end, various studies had been carried out in the area of students' numerical proficiency in physics and suggested ways to improve the numerical problems solving skills of physics students such as teachers' sound content knowledge among others.

Content knowledge encompasses the understanding and awareness of the specific body of knowledge and information that educators impart and that students are expected to acquire within a particular subject area, such as physics or mathematics. According to Marianne (2017), content knowledge includes the facts, concepts, theories, and principles that are integral to specific academic disciplines. She further posits that while content knowledge is intrinsically linked to academic competency, it is a complex construct that incorporates the skills, attitudes, and behaviors of educators, all of which significantly influence students' academic success in the classroom. Jason (2012) emphasizes that content knowledge pertains to teachers' comprehension of the subject matter. This implies that the primary objective of physics teachers' content knowledge is to enhance the planning and assessment of classroom interventions, particularly concerning the numerical components of physics. Additionally, content knowledge can be viewed as the foundational knowledge necessary for a physics teacher to effectively instruct on any topic within the discipline. In the context of this study, content knowledge refers specifically to the understanding of physics concepts, theories, laws, and principles.

It is important to emphasize that possessing and demonstrating adequate content knowledge is an essential attribute for physics teachers during the instructional process of numerical physics. This is crucial as teachers with strong content knowledge are better equipped to recognize the challenges that students face in grasping physics concepts, thereby facilitating a clearer understanding of the subject's structure and mitigating its complexities (Tsafe, 2013). Research conducted by Olisama, Odumosu, and Egho (2011) suggests that educators who have previously engaged in comprehensive study of the subjects they teach tend to be particularly effective. Furthermore, Ishola and Udofia (2017) corroborate the idea that the quality of a teacher's content knowledge has a more significant impact on student performance than the students' prior academic achievements or the institutions they attend. Consequently, this implies a potential correlation between teachers' content knowledge and students' performance in science disciplines, including physics. The implication is that when students are instructed by proficient teachers who possess substantial content knowledge, notable enhancements in student performance, particularly in numerical skills, are likely to occur.

Numerical proficiency in the field of physics refers to the capacity to address mathematically based problems, which is essential for clarifying theoretical principles within the discipline. This proficiency includes the mathematical and computational abilities that allow students to understand the relationships between different physics concepts, thus promoting more effective problem-solving strategies. According to Skills Panorama (2020), numerical proficiency involves the ability to access, utilize, interpret, and communicate mathematical information and ideas, which is crucial for managing the mathematical challenges encountered in various aspects of adult life. Zewdie (2014) highlights that the capability to solve complex problems is a critical skill for individuals in the contemporary, rapidly changing technological environment. Given the inherently quantitative nature of physics, it encourages students to simplify problems through calculations that may be either memorized or obtained from external sources (Beiser, Mahajan & Choudhury, 2011). Students who demonstrate proficiency in physics are those who can convert complex physics equations into simpler terms, thereby effectively addressing numerical problems (Beiser, Mahajan & Choudhury, 2011). The authors further contend that a strong understanding of fundamental physics concepts, coupled with the ability to apply this knowledge to intricate formulas, significantly improves students' problem-solving skills in the realm of physics.

Problem-solving has been recognized as a crucial element affecting academic success in scientific fields, especially in Physics. This issue stems from students' inclination to memorize solutions provided by instructors instead of cultivating a true comprehension of problem-solving methodologies, which is a hallmark of conventional teaching methods. Studies revealed that a considerable proportion of Physics instructors agree that students who are new to the subject often arrive with insufficient preparation for executing calculations (Frederick & Joan, 2010). Moreover, research indicates that although students may perform well in addressing standard quantitative Physics problems, they often lack a solid understanding of the fundamental conceptual or qualitative dimensions of the discipline (Tenzin, 2019). This scenario highlights the fact that students frequently develop computational abilities through rote learning, lacking a thorough grasp of the principles that underpin their solutions. Additionally, it is commonly acknowledged in Physics education that students often replace values in equations without fully understanding when to assign a parameter a positive, negative, or zero value.

The numerical aspects of physics frequently generate anxiety among students. The mere reference to physics often triggers a desire to avoid the subject, largely due to its reliance on mathematical concepts. Only a small number of students who confront these challenges and achieve success are viewed as champions of the field. This viewpoint, however, is fundamentally flawed, as physics can be made accessible to all learners when taught effectively by a knowledgeable physics teacher. However, according to (Callahan, Cannon, Chesick, Mackin, Mandel & Wennin, 2011), excellence in high school physics which includes high numerical proficiency in physics problem solving depends on the role of the teacher. Without a well-educated teachers, the arch of excellence in high school physics collapses.

Therefore, it is crucial to examine the relationship between teachers' content knowledge and students' numerical abilities. Studies such as Odumosu, Olisama and Areelu (2018) revealed that students were affected by teacher content knowledge in algebraic achievement. In contrast, Olfos, Goldrine and Estrella (2014), the constructivist-oriented subcomponent of the teachers' Content knowledge showed a non-significant association with student learning. Importantly, neither study specifically focused on students' numerical capabilities. To the best of the researcher's knowledge, there has been no prior research investigating the link between teachers' Content knowledge and students' numerical understanding. Consequently, it is against this premise that the researcher examines the predictive power of teachers' Content knowledge on students' numerical proficiency in solving physics problems to fill the gaps and substantiate the already existing literatures.

Research Question

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

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

Hypothesis

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

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

Method

The investigative framework utilized in this study is characterized by a correlational research design. According to Nworgu (2015), the primary objective of a correlational study is to elucidate the nature of the relationship between two or more variables. This design is particularly appropriate for the present research, which aims to evaluate the predictive ability of pedagogical competency concerning students' numerical skills in addressing physics problems. The study is geographically centered in the Onitsha education zone of Anambra State, which includes three local government areas: Onitsha North, Onitsha South, and Ogbaru. Within this educational zone, there are thirty-two public secondary schools, distributed as follows: sixteen in Onitsha North, six in Onitsha South, and ten in Ogbaru. The selection of this region is based on its status as a commercial hub, where many educators are also engaged in business activities, often leading to a lack of emphasis on their professional competencies (content knowledge inclusive) in teaching.

The population for this study consists of 61 physics educators (4 male and 57 female) and 6,348 SS2 students from all 32 public secondary institutions in the region as documented by the Statistical Office of the Post Primary School Service Commission (PPSSC) in the Onitsha education zone (2023). The research sample comprises 220 individuals, including 20 physics teachers (4 male and 16 female) and 200 physics students, who were randomly chosen from 20 distinct schools.

Two assessment tools, namely the Physics Teachers' Content Knowledge Rating Scale (PTCKRS) and the Physics Students' Numerical Proficiency Test (PSNPT), were employed for the purpose of data collection. These instruments were meticulously designed and structured by the researchers to align with the objectives of the current study, drawing upon empirical sources for their development. The PTCKRS comprises twenty theoretical questions specifically formulated for physics educators, with all items sourced from the domain of field-electricity. Each correct response is awarded 5 points, culminating in a maximum score of 100% for all correct answers. In contrast, the PSNPT consists of twenty calculation-based questions aimed at assessing students' numerical proficiency in solving physics problems. Validation of these instruments was conducted by three experts: one from the Measurement and Evaluation unit and two from the Physics Education unit, all affiliated with the Faculty of Education at the University of Nigeria, Nsukka (UNN). The reliability of both the PTCKRS and PSNPT was assessed through scorer reliability, utilizing the Kendall coefficient of concordance. This approach was selected due to the involvement of three raters who evaluated the responses from both teachers and students. The calculated reliability coefficients were 0.80 for the PTCKRS and 0.71 for the PSNPT. The instruments were administered and collected promptly, and the data obtained were analyzed using simple linear regression for the research question and analysis of variance for the hypothesis.

Results

The results of the study are presented in the tables below

Research Question 1

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

Table 1

Regression coefficient of the predictive power of teacher's 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	.462[a]	.213	.170	19.52387

a. Predictors: (Constant), PTKT

Table 1 presents a regression coefficient with an R value of 0.462, indicating that a teacher's content knowledge serves as a moderate predictor of students' numerical proficiency in addressing physics problems. Furthermore, the coefficient of determination (R squared) of 0.213 suggests that teacher content knowledge accounts for 21.3% of the variance in students' numerical proficiency in solving physics problems.

Hypothesis 1: Physics teacher's 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 content knowledge on students' numerical proficiency in solving physics problems.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1862.480	1	1862.480	4.886	.040[b]
	Residual	6861.270	18	381.182		
	Total	8723.750	19			

a. Dependent Variable: NP
b. Predictors: (Constant), PTKT

Table 2 presents the results indicating $F(1, 18) = 4.886$, $p = 0.040$, which is less than the 0.05 significance threshold. This finding suggests that the null hypothesis is rejected in favor of the alternative hypothesis, as the p-value falls below the 5% significance level. Consequently, it can be concluded that the content knowledge of physics teachers serves as a significant predictor of students' proficiency in numerically solving physics problems.

Discussion

Research findings indicate that a teacher's content knowledge serves as a moderate predictor of students' numerical proficiency in addressing physics problems. This suggests that a teacher's understanding of the subject is a crucial factor influencing students' ability to solve such problems. The underlying rationale may be that individuals can only impart knowledge that they possess. Educators with strong content knowledge effectively leverage this expertise to enhance learning, thereby conveying information to students in a meaningful manner. Such educators often earn the admiration of their students, who may seek to emulate them. A teacher equipped with robust content knowledge, including mathematical and numerical skills, presents concepts to students in a fluid and engaging manner, thereby facilitating the learning process.

The findings align with the research conducted by Lee, Robert, and Capraro (2018), which demonstrated that teachers' subject matter expertise positively correlates with students' problem-solving abilities. Similarly, the work of Olasehinde-Williams, Yahaya, and Owolabi (2018) supports the current study by showing that teachers' depth of subject knowledge significantly predicts students' academic success in English Language and Mathematics. Furthermore, the research by Odumosu, Olisama, and Areelu (2018) corroborates the present findings by indicating that teachers' content knowledge influences students' performance in algebra. Additionally, the study by Ibe, Nworgu, and Anyaegbunam (2016) explored the impact of teachers' subject matter knowledge on the academic achievement of secondary school biology students, revealing that factors such as teachers' gender, teaching experience, qualifications, interpersonal relationships with students, and subject knowledge significantly affect students' success in Biology.

Conclusion

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

Recommendation

Given the findings of the study, it is recommended that educators enhance their comprehension of physics concepts to improve their capacity to teach numerical skills effectively to their students. Additionally, teacher training institutions should prioritize that all prospective teachers should attain the necessary content knowledge by the time of their graduation.

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