Influence of Teachers' Pedagogical Content Knowledge on Learners' Mathematical Problem-Solving Competence in Junior Schools Bungoma County, Kenya

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ABSTRACT

Education is a critical equalizer, and every learner deserves quality, differentiated instruction. Kenya's Competency-Based Education (CBE) aims to nurture holistic learners equipped with problem-solving and other essential competencies. However, the effectiveness of CBE depends heavily on teachers' Pedagogical Content Knowledge (PCK)—their ability to tailor instruction to diverse learners while mastering subject matter. Despite its importance, little research has examined how PCK influences competency development in junior schools, particularly in rural settings like Webuye. This study bridges that gap by investigating the relationship between teachers' PCK and learners' achievement in problem-solving in Webuye-East and Webuye-West sub-counties. The objective of the study was to determining the relationship between PCK and learners' problem-solving competence. Grounded in Vygotsky's Social Interaction Theory, the research employed a descriptive survey research design. The target population included heads of institution, mathematics teachers, Grade 8 learners from all 149 junior schools in the two sub-counties. A sample of 686 respondents was selected—373 learners, 206 mathematics teachers and 107 head of institutions. Data was collected via questionnaires, interviews, learner assessment tests, and lesson observations. Validity was ensured through expert review, and reliability was confirmed using Cronbach's alpha ($\alpha > 0.7$). A Pearson correlation analysis showed a weaker but significant correlation with problem-solving ($r = 0.23$, $p = 0.022$), leading to rejection of the null hypothesis. The study concluded that while PCK enhances competency-based learning, systemic barriers limit its impact. Recommendations include: Continuous teacher retooling to align PCK with CBE demands. Adoption of learner-centered approaches (e.g., collaborative learning and integration of technology) to strengthen problem-solving. deficits. These findings benefit the Ministry of Education in policy making, teacher trainers in curriculum reviews, and schools in optimizing instructional practices.

Keywords: Pedagogical Content Knowledge (PCK); Problem-Solving Competence; Competency-Based Education (CBE); and Junior School Mathematics

INTRODUCTION

Education serves as a vital equalizer in society, and quality instruction remains central to equitable learning outcomes. In line with this vision, Kenya introduced the Competency-Based Curriculum (CBC) in 2017 under its Competency-Based Education (CBE) framework. The CBE aims to develop learners who are not only knowledgeable but also equipped with problem-solving, critical thinking, and creativity—competencies essential for navigating the 21st-century world. At the core of implementing this curriculum successfully is the teacher's Pedagogical Content Knowledge (PCK), which encompasses both mastery of subject matter and the pedagogical strategies necessary to effectively deliver content tailored to diverse learner needs.

Shulman (1986) defined PCK as the unique blend of content and pedagogy that is central to teaching expertise. This includes the ability to present concepts in meaningful ways, address student misconceptions, and design instruction that fosters deep understanding. Later scholars, such as Koehler and Mishra (2006), expanded the

concept to include technology integration, forming the Technological Pedagogical Content Knowledge (TPCK) framework. Theoretically, this study was grounded in Vygotsky's Social Interaction Theory, which posits that learning occurs most effectively through socially mediated interactions, emphasizing the teacher's role in scaffolding learners' cognitive development—particularly in complex tasks like mathematical problem-solving.

Globally, several education systems have prioritized the development of problem-solving competencies in mathematics. Countries like Singapore, the Netherlands, and England have implemented curriculum reforms and teacher development initiatives focused on embedding problem-solving at the core of instruction (Clark, 2009). However, in many African and developing contexts, including Kenya, barriers such as limited teaching resources, inadequate teacher preparation, and overreliance on traditional methods remain prevalent. Tambara (2015) emphasized the need for African educators to shift toward problem-based learning and adopt strategies that encourage active engagement with mathematical tasks. Despite national efforts to strengthen CBC implementation, studies in Bungoma County reveal persistent gaps in teacher preparedness and the integration of learner-centered approaches in mathematics classrooms (Chele, Maiyo, & Kikechi, 2020; Mukenya, 2020).

In Webuye-East and Webuye-West sub-counties of Bungoma, the situation is further exacerbated by a shortage of trained Junior School teachers, high learner-to-teacher ratios, and a lack of technological infrastructure (Standard Newspaper, 2023). Many of the teachers deployed to Junior Schools are repurposed primary school educators with limited pedagogical training specific to the CBC. This has raised concerns about their ability to foster problem-solving competence among learners—an outcome that is central to the new curriculum. Yet, there is a lack of empirical research examining how teachers' PCK specifically influences problem-solving outcomes in rural Junior School settings, which this study seeks to address.

The purpose of this study is to investigate the influence of mathematics teachers' Pedagogical Content Knowledge on learners' problem-solving competence in Junior Schools in Webuye-East and Webuye-West sub-counties. Specifically, the study aims to determine the relationship between teachers' PCK and learners' problem-solving achievement, and to explore the contextual factors that may hinder effective PCK application in these schools.

This research is significant for several stakeholders. It informs the Ministry of Education on critical areas for teacher support and policy refinement, offers insights for teacher training institutions to improve pre-service and in-service programs, and provides practical implications for school administrators seeking to optimize mathematics instruction. By focusing on a relatively under-researched rural setting, the study also contributes to the broader discourse on equitable and context-sensitive implementation of competency-based education in Sub-Saharan Africa.

Research Hypotheses

The null hypothesis that were tested by Pearson correlation coefficient in this study included:

H_{o1}: Teachers' Pedagogical Content Knowledge has no statistically significant influence on learners' achievement of problem-solving competence in Junior Schools in Webuye - East and Webuye - West sub counties.

LITERATURE REVIEW

Review of Related Empirical and Theoretical Literature

Pedagogical Content Knowledge (PCK) was first conceptualized by Shulman (1986) as a specialized type of teacher knowledge that integrates subject matter expertise with pedagogical skill. This dual knowledge enables teachers to present content in ways that are accessible and meaningful to learners, taking into account common misconceptions and varied learning needs. Vygotsky's (1978) Social Interaction Theory further supports this view by positing that learning is a socially mediated process in which teachers scaffold knowledge within learners' zones of proximal development. In mathematics education, PCK plays a critical role in helping students engage with abstract and complex concepts through appropriate instructional design, dialogue, and questioning techniques.

Several empirical studies have established a positive correlation between teachers' PCK and student achievement. For instance, Morrison et al. (2015) demonstrated that teachers with strong PCK in mathematics were more likely to use diagnostic assessments, tailor feedback, and employ student-centered strategies that enhance conceptual understanding. Similarly, Tambara (2015), in an African context, emphasized the importance of teacher knowledge in transitioning from rote instruction to inquiry-based and problem-solving approaches. These findings align with the premise that enhancing teachers' PCK is instrumental in fostering critical competencies among learners, especially in STEM disciplines where higher-order thinking skills are essential.

Definition of Core Concepts

Pedagogical Content Knowledge (PCK) refers to the intersection of content expertise and pedagogy that enables teachers to teach specific subjects effectively (Shulman, 1986). It encompasses understanding what makes the learning of specific topics easy or difficult, anticipating misconceptions, and using various representations to enhance comprehension.

Competency-Based Education (CBE) is an approach to learning that emphasizes the development of skills, attitudes, and knowledge that are essential for lifelong learning and success in real-life contexts. It prioritizes learner-centered instruction, formative assessment, and the acquisition of competencies such as communication, collaboration, critical thinking, creativity, and problem-solving (KICD, 2017).

Problem-solving in mathematics refers to a learner's ability to apply knowledge, reasoning, and logical thinking to resolve non-routine or unfamiliar problems. It is not merely a procedural skill but a higher-order cognitive process involving exploration, strategy selection, and reflective thinking (Polya, 1957). Problem-solving is recognized globally as a key outcome of quality mathematics education.

National and International Perspectives

Internationally, countries like Singapore, England, and the Netherlands have emphasized problem-solving in mathematics education as a strategic priority. Singapore's Thinking Schools, Learning Nation (TSLN) and Teach Less, Learn More (TLLM) initiatives streamlined curriculum content to allow for deeper engagement with mathematical problems (Clark, 2009). England invested in professional development programs and curriculum materials aimed at embedding problem-solving in everyday teaching (Clark, 2009). In contrast, Atiah (2020) found that traditional teaching practices in Indonesia hindered the development of higher-order skills due to limited technology use and teacher-centered methodologies.

In the African context, several studies underscore the importance of PCK and the challenges surrounding its application. Tambara (2015) identified a disconnect between policy goals and classroom practices in early mathematics education, calling for a shift toward problem-based learning and better support for teacher professional development. In Kenya, the introduction of the CBC aimed to position problem-solving and other competencies at the core of education. However, research has revealed systemic implementation challenges, including overcrowded classrooms, inadequate resources, and limited teacher preparedness (Chele, Maiyo, & Kikechi, 2020; Mukenya, 2020).

Identification of the Research Gap

While numerous studies have explored the impact of teacher knowledge on student achievement, few have specifically examined the influence of mathematics teachers' Pedagogical Content Knowledge on learners' problem-solving competencies within rural Kenyan contexts. Most existing research is either focused on general pedagogical practices or limited to urban and peri-urban settings. In Bungoma County—particularly in Webuye-East and Webuye-West sub-counties—schools face acute challenges such as high pupil-teacher ratios, insufficient training, and lack of instructional resources. Furthermore, many Junior School teachers are drawn from a pool of primary educators with limited exposure to CBC-aligned methodologies and insufficient PCK. This study addressed the critical gap in empirical evidence by investigating the relationship between mathematics teachers' PCK and learners' problem-solving performance in these rural sub-counties, thereby offering insights that can inform policy, teacher training, and classroom practice.

METHODOLOGY

This study adopted a descriptive survey research design to investigate the relationship between mathematics teachers' Pedagogical Content Knowledge (PCK) and learners' problem-solving competence in Junior Schools within Webuye-East and Webuye-West sub-counties of Bungoma County, Kenya. The design was deemed appropriate for collecting both quantitative and qualitative data from a large and diverse population in a naturalistic educational setting. The study was guided by Vygotsky's Social Interaction Theory, which emphasizes the role of scaffolding in knowledge construction—particularly relevant to understanding how teachers' instructional approaches impact learners' mathematical problem-solving development.

Target Population and Sampling Procedures

The study targeted a population of Grade 8 learners, mathematics teachers, and heads of institution from all 149 Junior Schools in Webuye-East and Webuye-West sub-counties. According to Ministry of Education (2023) records, Webuye-East has 11,160 learners and 248 teachers, while Webuye-West has 15,660 learners and 348 teachers.

Using stratified random sampling and proportional allocation, a total sample of 686 respondents was selected where 373 Grade 8 learners, 206 mathematics teachers, and 107 heads of institution. This sampling approach ensured representativeness across school types and sub-counties.

Data Collection Instruments

Multiple instruments were used to enhance the validity and richness of the data:

Questionnaires: For mathematics teachers focused on their pedagogical practices, knowledge of the Competency-Based Education, and perceptions of problem-solving competence.

Structured interviews: Captured in-depth insights from school heads regarding contextual challenges in implementing PCK.

Lesson observation checklists: Assessed the application of PCK in real classroom settings.

Learner assessment tests: Measured students' mathematical problem-solving competence based on CBE-aligned tasks.

Validity and Reliability of Instruments

Content validity was established through expert review by university-based education researchers and curriculum specialists from the Kenya Institute of Curriculum Development (KICD). Feedback was used to refine questionnaire items and observation criteria to align with the CBC framework.

To assess reliability, a pilot study was conducted in two schools outside the study sample. The internal consistency of the quantitative instruments was evaluated using Cronbach's alpha, with values exceeding 0.70, confirming acceptable reliability for both teacher and learner tools.

Data Collection Procedures

Data collection was carried out over six weeks with the support of trained research assistants. Ethical clearance was obtained from relevant educational authorities, and informed consent was secured from all participants, including assent from learners and permission from school administrators. Data were collected in four phases: Questionnaire for teachers, Interviews with selected Heads of Institution, Learner assessments, and Classroom lesson observations.

Data Analysis Techniques

Quantitative data were coded and analyzed using Statistical Package for the Social Sciences (SPSS) version 25.

Descriptive statistics (means, standard deviations, frequencies) were used to summarize respondents' characteristics and levels of PCK. A Pearson product-moment correlation was conducted to test the relationship between teachers' PCK and learners' problem-solving performance.

Qualitative data from interviews and observations were analyzed thematically using content analysis, which allowed for triangulation and deeper understanding of contextual variables influencing teaching and learning outcomes.

RESULTS AND FINDINGS

Response Rate

For HOI, only 60 out of the 107 sampled were reached and interviewed representing 56.1% respondents from this cadre. The other part of HoIs could not be reached due to logistical challenges in their work schedules. This shows that just over half of the Head of Institution participated in the study. In contrast, teachers demonstrated a significantly higher response rate, with 173 out of 206 responding to the questionnaires and returning them yielding an 84.0% return rate. This high level of engagement reflected strong responsiveness and interest from teachers. Among students, 240 out of 373 sampled attempted the test and submitted their work to their teachers who submitted it to the researcher resulting in a 64.3% return rate.

Majority of teacher respondents were female 57.8% (100 teachers) and male 42.2%(73 teachers). This indicated that females made up a larger proportion of the teaching workforce in the sampled schools. This indicates relatively balanced representation of both genders that suggests efforts to promote gender equality in the teaching profession. The majority (86.2%) of teachers are between 25 and 40 years old, with the largest proportion in the 31–40 age group (45.7%). Only 13.9% of teachers are aged 41–50, which may reflect early retirements, career changes, or limited recruitment of older educators. The 54.9% of the sampled teachers had fewer than five years of experience. Only 6.3% of teachers had 16 or more years of experience, indicating potential challenges in retaining veteran educators. On training and teaching 78.6% of teachers received training in either language (42.8%, n=74) or Science and Mathematics (35.8%, n=62), indicating a strong institutional emphasis on these core subjects within teacher preparation programs. By contrast, significantly fewer teachers were trained in humanities (15.0%, n=26) and technical fields (6.4%, n=11), suggesting these areas may be under-prioritized in teacher development initiatives.

Table 1: Teacher Training Backgrounds and Current Teaching Assignments

Subject Area	**Trained Teachers (%)**	**Currently Teaching (%)**	**Discrepancy**
Language	42.8 (n=74)	36.4 (n=63)	-6.4
Science & Math	35.8 (n=62)	20.2 (n=35)	-15.6
Humanities	15.0 (n=26)	24.9 (n=43)	+9.9
Technical Subjects	6.4 (n=11)	18.5 (n=32)	+12.1
Total	**100.0 (n=173)**	**100.0 (n=173)**	

Analysis of current teaching assignments revealed several important patterns. While language remained the most commonly taught subject (36.4%), there is a notable 6.4 percentage point decrease from the number of teachers trained in this area. Science and Mathematics showed an even more significant discrepancy, with 15.6% fewer teachers currently assigned to these subjects than were originally trained in them. Conversely, both humanities and technical subjects demonstrated substantial positive discrepancies (+9.9% and +12.1% respectively), indicating that many teachers are being assigned to these subjects despite lacking specialized training.

These findings suggested several important implications for educational policy and practice. The substantial gap in technical education capacity is particularly concerning, with nearly three times as many teachers assigned to

technical subjects (18.5%) as were specifically trained for them (6.4%). This mismatch reflected systemic shortages in these subject areas or evolving curriculum demands that outpaced teacher preparation program.

On professional development majority of teachers (55.5%, n=96) had received post-qualification training in teaching methods or pedagogy (retooling), a substantial portion (44.5%, n=77) had not. This finding raised critical concerns about the continuity and accessibility of professional development for educators. Given the rapid evolution of pedagogical approaches, curriculum reforms (such as competency-based education), and technological advancements in teaching, ongoing retooling was essential to ensure teachers remained effective in their practice (Darling-Hammond, 2017).

Majority of the learner respondents were girls 58.3 % (140 girls) and boys 41.7 % (100 boys).The learner respondents were between the ages of 12 years to 16 years. Those who were 12 years were the least with 9.6% (n=23), 13 years 27.9 %(n=67), 14 years who were the majority formed 37.5 %(n=90), 15 years were 15 % (n=36) and 16 years formed 10 % (n =24).

In conclusion, the analysis of the provided data revealed a predominantly young, female teaching workforce employed largely in public schools. While the majority of teachers held bachelor's degrees, there was a notable lack of post-qualification training with almost half of the Junior secondary school teachers and advanced education. Addressing these gaps through targeted interventions, such as mandatory professional development programs, mentorship initiatives, and incentives for advanced education, could enhance the quality of education and ensure a more robust and sustainable teaching profession.

Determining the relationship between teachers' Pedagogical Content Knowledge and learners' achievement of problem-Solving competence.

The objective of the study sought to determine the relationship between teachers' pedagogical content knowledge and learners' achievement of problem-solving competence. Data was collected from 173 teachers in junior schools across Webuye East and Webuye West sub-counties. Teachers' PCK was measured using a 10-item Likert scale questionnaire, with responses ranging from 1 (Strongly Agree) to 5 (Strongly Disagree) presented in table below. Learners' problem-solving achievement was measured using standardized problem-solving tests, and the average scores for each class were recorded.

The analysis of teachers' pedagogical content knowledge (PCK) and its relationship with learners' problem-solving achievement involved a two-step process. First, a composite score for teachers' PCK was calculated by averaging their responses across the 10 items. This composite score provided a comprehensive measure of each teacher's overall level of PCK, integrating various aspects such as integration of subject matter with pedagogical knowledge, use of diverse representations, and encouragement of student participation.

Next, Pearson's correlation analysis was conducted to examine the relationship between teachers' PCK composite scores and learners' problem-solving achievement scores. This statistical method used Pearson's correlation coefficient (r) to measure the strength and direction of the linear relationship between two continuous variables. The results indicated that teachers generally perceive themselves as having strong PCK related to problem-solving, with mean scores ranging from 3.54 to 4.38.

Table 2 : Teachers' Pedagogical Content Knowledge and students' problem-solving

PCK Items	n	Mean	Mode	Std. Deviation	SA	A	N	D	SD
i. My Pedagogical Content Knowledge influences my students' problem-solving skills.	173	4.06	4	0.826	28.3	56.1	10.4	3.5	1.7
ii. I effectively incorporate problem-solving strategies in my teaching practices.	173	4.28	4	0.693	39.9	49.7	8.7	1.7	
iii. I provide opportunities for students to apply problem-solving skills in real-world scenarios.	173	4.2	4	0.715	35.8	50.3	12.1	1.7	

iv. I assess students' problem-solving competence regularly and provide constructive feedback.	173	4.17	4	0.773	36.4	48	12.1	3.5	
v. I tailor my teaching methods to enhance students' problem-solving abilities.	173	4.32	4	0.707	44.5	45.1	8.7	1.7	
vi. I create a supportive environment that encourages students to explore various problem-solving approaches.	173	4.36	5	0.665	46.8	42.8	10.4		
vii. I collaborate with colleagues to improve problem-solving instruction across subjects.	173	4.29	4	0.723	43.4	44.5	10.4	1.7	
viii. I continuously seek professional development opportunities to enhance my problem-solving teaching strategies.	173	3.54	4	1.108	20.8	37	20.2	19.1	2.9
ix. I observe growth in students' problem-solving skills over time as a result of my teaching methods.	173	4.05	4	0.714	26	54.3	17.9	1.7	
x. I encourage students to collaborate and communicate effectively to solve complex problems.	173	4.38	5	0.694	50.3	37.6	12.1		

Hypothesis testing

The Pearson's correlation analysis was conducted to test the relationship between teachers' PCK composite scores and learners' problem-solving achievement scores. The results were presented in the correlation matrix in table 3 below:

Table 3: Correlation between teachers' PCK and Learners' Problem-Solving Achievement

		Problem solving	Teachers' PCK
Problem solving	Pearson Correlation	1	.227
	Sig. (2-tailed)		.022
	N	240	173
Teachers' PCK	Pearson Correlation	.227	1
	Sig. (2-tailed)	.022	
	N	173	173

The correlation analysis between learners' problem-solving competence and teachers' Pedagogical Content Knowledge (PCK) revealed a statistically significant but weak positive relationship. The Pearson correlation coefficient of 0.227 ($p = 0.022$) the $r^2 = 0.0515$ this indicated that increase in teachers' PCK accounts for 5.15 % increase in learners' problem-solving competence meaning that as teachers' PCK scores increase, there is a slight tendency for learners' problem-solving performance to improve as well. Therefore, the hypothesis that there was no statistically significant relationship between teachers' PCK and learners' achievement of problem-solving competence in Junior Schools in Webuye-East and Webuye-West sub-counties was rejected.

The findings align with theoretical expectations that PCK contributes to learners' outcomes but underscore the complexity of educational processes. The weak correlation implies that factors beyond PCK, such as resource availability, assessment practices, or socio-cultural contexts, likely play substantial roles in shaping problem-solving competencies. Notably, the study's methodology—using teacher self-reports for PCK may have introduced response bias or obscured individual learner variability.

DISCUSSION

The results highlight a dynamic yet constrained educational landscape. While most teachers reported high levels of Pedagogical Content Knowledge (PCK), especially in collaborative and adaptive problem-solving instruction, the weak but significant correlation ($r = .227$, $p = .022$) suggests that PCK alone may not guarantee strong learner outcomes. This aligns with Vygotsky's Social Interaction Theory, emphasizing the need for environmental support beyond the teacher—such as adequate resources, manageable class sizes, and continuous professional development—for effective scaffolding (Vygotsky, 1978).

The disparities between teacher training and subject assignments, particularly in Technical and Humanities areas, indicate systemic misalignments. Teachers teaching outside their areas of preparation may deliver content with less confidence or clarity, potentially undermining instructional quality. This supports prior findings that insufficiently aligned pre-service training reduces the efficacy of competency-based approaches (Morrison et al., 2015; Tambara, 2015).

Moreover, approximately 45% of teachers lacked post-qualification training, which likely contributes to stagnation in pedagogical growth and reduced alignment with CBC ideals. The lower mean score ($M = 3.54$) on seeking professional development correlates with this gap. Literature emphasizes the importance of periodic retooling for sustaining PCK and, by extension, learner competencies (Darling-Hammond, 2017). Thus, without systemic capacity-building, PCK cannot fully translate into enhanced problem-solving outcomes.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study confirmed a statistically significant, though modest, positive relationship between mathematics teachers' PCK and learners' problem-solving competence in Webuye-East and Webuye-West sub-counties. Still, the low variance explained (≈5.2%) illuminates the complex interplay of contextual factors—such as training-to-assignment mismatches, limited professional development, overcrowding, and resource constraints—that moderate this relationship. For competency-based reforms like CBE to succeed, PCK must be strengthened within an enabling educational ecosystem.

Recommendations

1. The Ministry of Education and Teachers Service Commission should institutionalize regular retooling to align teachers' skills with CBE requirements, prioritizing problem-solving and pedagogical innovation.
2. Authorities should match teacher specialization with subject assignments and recruit additional teachers to balance subject distribution—particularly in Technical and Science areas.
3. Government and school leadership must allocate resources—manipulatives, ICT tools, and learner-centered materials—to facilitate PCK application and scaffold learner problem-solving.
4. Schools should establish in-house communities of practice that encourage teachers to share effective PCK strategies and co-design collaborative problem-solving lessons.
5. Future studies should incorporate classroom-level variables (e.g., resource inventories, class size metrics) and use longitudinal and experimental designs to unpack causal effects of PCK on learner outcomes.

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