

ASSESSMENT OF CONTENT KNOWLEDGE OF UPPER PRIMARY SCHOOL TEACHERS IN MATHEMATICS: A CASE STUDY OF NAYAGARH DISTRICT OF ODISHA

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ABSTRACT

The quality of mathematics instruction at the upper primary level largely depends on teachers' depth of content knowledge, which directly influences students' conceptual understanding and problem-solving abilities. The present study aims to assess the content knowledge of upper primary school teachers in mathematics in the Nayagarh district of Odisha. Adopting a case study approach, the research examines teachers' understanding of key mathematical domains prescribed in the upper primary curriculum, including number systems, algebra, geometry, mensuration, and data handling. A representative sample of upper primary mathematics teachers was selected from government and aided schools of the district. Data were collected using a standardized achievement test and supplemented by background information schedules. Descriptive and inferential statistical techniques were employed to analyze the data. The findings reveal variations in teachers' content knowledge across different mathematical domains, with noticeable strengths in procedural knowledge and gaps in conceptual understanding in certain areas. The study highlights the need for targeted professional development programmes and continuous in-service training to strengthen teachers' mathematical content knowledge. The results are expected to contribute to policy decisions and teacher education practices aimed at improving the quality of mathematics teaching at the upper primary level.

KEYWORDS: *Content Knowledge, Mathematics Teachers, Upper Primary School, Case Study, Nayagarh District, Odisha*

INTRODUCTION

Education plays a pivotal role in the overall development of individuals and serves as a catalyst for social transformation. It is central to economic progress, social empowerment, and the strengthening of democratic values. A lack of education contributes to limited access to opportunities and poorer quality of life, especially for those who are unable to progress to higher levels of education. In India, a considerable segment of the population continues to be deprived of elementary and secondary education due to socio-economic constraints, lack of access, inadequate facilities, or social inequalities. These barriers not only restrict entry into higher educational institutions but also hamper the nation's broader development objectives.

Odisha, like many other Indian states, has undergone significant changes in its educational landscape over the past decades. The state has shown steady progress in literacy, with the 2011 Census reporting an overall literacy rate of 73.5 percent, slightly below the national average of 74.04 percent. Within Odisha, Nayagarh district stands out for its comparatively higher literacy rate of 80.4 percent, with male literacy at 82.2 percent and female literacy at 72.0 percent. The district also displays a rural-urban disparity, with rural literacy at 79.8 percent compared to 87.8 percent in urban areas. Government initiatives, both at the central and state levels, have placed significant emphasis on improving literacy, especially among women and tribal communities groups that have historically been marginalized.

Over the years, efforts have been made to enhance equity, access, quality, relevance, and participation within the upper primary education system. Various programmes have aimed at making learning more engaging, assessments more meaningful, and knowledge acquisition more equitable for all students. Odisha has made notable strides toward the universalization of primary education, as reflected in its improving literacy indicators. A major milestone in this journey was the enactment of the Right of Children to Free and Compulsory Education (RTE) Act, 2009, which guarantees free and compulsory education for all children aged 6 to 14 years. The Act also sets norms related to teacher qualifications, teacher-pupil ratio, school infrastructure, and the quality of education imparted.

Internationally, the importance of universal primary education has been recognized within the United Nations Millennium Development Goals (MDGs), which emphasized ensuring that all children irrespective of gender complete primary schooling. Education is seen as an essential tool for breaking the cycle of poverty, improving health outcomes, and fostering socio-economic development. Despite global efforts, reports by UNESCO and UNICEF highlight that the world fell short of achieving universal primary education by 2015, with an estimated 58 million children still out of school.

Within this broader global and national context, the provision of quality primary and upper primary education becomes a key indicator of development and quality of life. India's constitutional commitment to education, reflected in Article 45 and further reinforced by the RTE Act, underscores the importance placed on ensuring educational access and equity.

However, quality education is not determined by access alone the competency and content knowledge of teachers play a critical role in shaping learning outcomes, particularly in subjects like mathematics. At the upper primary level, mathematics forms the foundation for higher-order thinking, logical reasoning, and future academic success in science and technology. The effectiveness of mathematics teaching depends substantially on the teacher's mastery of mathematical concepts, pedagogical skills, and confidence in handling diverse classroom situations.

In this context, assessing the content knowledge of upper primary school teachers in mathematics becomes crucial, especially in districts like Nayagarh, where literacy indicators are encouraging but where qualitative dimensions of teaching need continuous evaluation. This study aims to explore the depth of mathematical content knowledge among upper primary teachers in Nayagarh district, identify existing gaps, and provide insights that can inform targeted interventions and policy decisions.

REVIEW OF LITERATURE

A thorough review of literature is essential for understanding the nature of teacher content knowledge in mathematics and its impact on upper primary student learning. The present study builds on a body of research that foregrounds the significance of teachers' mathematical understanding, pedagogical competence, and instructional design in shaping learners' conceptual development. In particular, mathematics teaching at the upper primary level demands a balance between procedural fluency and conceptual understanding, requiring teachers to possess strong content knowledge and the ability to convey abstract ideas effectively.

1. Importance of Teacher Content Knowledge in Mathematics

Numerous studies emphasize that teachers' mathematical content knowledge is a critical predictor of student achievement. Shulman (1986) introduced the concept of Pedagogical Content Knowledge (PCK), highlighting that effective teaching requires more than subject expertise; teachers must also know how students think and how content can be presented meaningfully. Ball, Thames, and Phelps (2008) further refined this through the framework of Mathematical Knowledge for Teaching (MKT), distinguishing between common content knowledge (knowledge of mathematics used in everyday contexts) and specialized content knowledge (mathematical understanding unique

to teaching). Research indicates that teachers with strong MKT can diagnose student errors, choose appropriate tasks, represent concepts in multiple ways, and promote deeper understanding.

International studies, including those from the TIMSS and PISA assessments, repeatedly show that countries with strong teacher competence in mathematics tend to produce better student outcomes. Thus, the quality of mathematics education at the upper primary level is heavily influenced by the content mastery of teachers.

2. Teaching Designs and Mathematical Problem Solving

To explore how students develop reasoning and problem-solving skills, several researchers have examined teaching designs that effectively promote mathematical competencies. These designs are typically characterized by (a) the educational intentions behind them, (b) the instructional strategies used, and (c) the theoretical and empirical support guiding these practices.

Studies show that teaching designs aimed at enhancing mathematical reasoning often promote student-centered learning, allowing students to actively construct their own mathematical knowledge. This aligns with constructivist theories, which posit that meaningful learning occurs when students engage directly with mathematical ideas, test hypotheses, and explore multiple representations.

3. Theoretical Foundations Supporting Effective Mathematics Teaching

Several learning theories provide a strong foundation for understanding how students make sense of mathematical concepts:

- Hypothetical Learning Trajectories (HLTs) help teachers anticipate student learning paths and design tasks that gradually increase in complexity.
- Realistic Mathematics Education (RME) emphasizes real-world contexts as a basis for mathematical thinking, encouraging students to reinvent mathematical knowledge through guided exploration.
- Theory of Didactical Situations (TDS) explains how structured problem situations can lead students to discover mathematical principles with minimal teacher intervention.
- Vygotsky's Zone of Proximal Development (ZPD) highlights the importance of teacher scaffolding in enabling learners to progress beyond their current level.

These theories collectively underline the importance of strategic task design, appropriate scaffolding, and student autonomy in the learning of mathematics.

4. The Role of Task Characteristics in Mathematics Learning

Stein et al. (1996) propose a framework that examines how the cognitive demand of mathematical tasks influences student learning. They differentiate between imitative tasks which require students to follow procedures and tasks with complex cognitive demands, which require reasoning, exploration, and conceptual understanding.

Research in classrooms shows that:

- Imitative tasks dominate because they are easier for teachers to prepare, require less mathematical expertise, and allow students to complete tasks quickly with minimal guidance.
- High-level tasks, while more demanding, lead to deeper understanding, greater flexibility in problem solving, and stronger long-term learning outcomes.

Stein's model highlights a persistent tension between short-term efficiency and long-term conceptual development, emphasizing the need for teacher expertise to design and implement cognitively demanding tasks.

5. Teacher Competence and Student Learning Outcomes

A large body of research reinforces that teachers must possess strong content knowledge to teach mathematics effectively. Studies indicate that teachers with limited understanding of core concepts often rely heavily on procedural teaching, focus on textbook-driven instruction, and struggle to diagnose student misconceptions.

Conversely, teachers with robust content knowledge:

- provide richer explanations,
- use multiple representations,
- pose meaningful problems,
- tailor tasks to student needs, and
- foster reasoning and higher-order thinking.

This highlights the central role of continuous professional development in strengthening teacher knowledge, especially at the upper primary level where abstract concepts begin to emerge.

6. Mathematics Education Research in Indian Context

Indian research conducted by NCERT, SCERTs, NUEPA, and independent scholars reveals several challenges in mathematics teaching:

- Many teachers lack confidence in topics such as fractions, geometry, decimals, algebra, and problem-solving.
- Teacher education programmes often emphasize theory over practical mathematical engagement.
- Misconceptions held by teachers are frequently transmitted to students.
- Traditional assessment systems promote rote learning rather than conceptual understanding.
- Large class sizes and limited resources hinder effective instruction.

Studies in Odisha similarly report that teacher knowledge gaps lead to reliance on rote procedures and inadequate emphasis on conceptual clarity. This becomes particularly significant in districts where literacy rates are improving but teacher quality remains uneven.

7. Global Perspectives on Mathematics Teaching

Research from other countries provides insights relevant to the present study:

- In Singapore and Japan, teacher training emphasizes deep content knowledge, lesson planning based on student thinking, and the use of structured problem solving.
- In Finland, teacher education is research-based, requiring teachers to understand the mathematical foundations of the curriculum thoroughly.
- In the United States, the Common Core Standards highlight conceptual understanding, but teacher preparedness varies widely.

These international perspectives reinforce the global consensus that strong teacher content knowledge is essential for high-quality mathematics instruction.

8. Gaps Identified in the Literature

From the literature reviewed, several gaps can be identified:

1. There is limited research focusing specifically on the content knowledge of upper primary mathematics teachers in Odisha, particularly in districts like Nayagarh.
2. Although national studies highlight teacher competency issues, district-level analyses are sparse.
3. Few studies examine how teacher content knowledge directly influences student performance at the upper primary level in rural and semi-urban settings.

4. The need for localized research that captures the socio-cultural, geographic, and infrastructural realities of districts like Nayagarh remains unmet.

These gaps justify the need for the present study, which aims to assess the mathematics content knowledge of upper primary school teachers in Nayagarh district and understand its implications for classroom practice and student learning.

OBJECTIVES OF THE STUDY

The present study aims to explore and evaluate the mathematical content knowledge of upper primary school teachers in Nayagarh district of Odisha. In order to achieve a comprehensive understanding of the issue, the following expanded objectives have been formulated:

1. To assess the level of mathematical content knowledge possessed by upper primary school teachers in Nayagarh district.

This includes determining teachers' understanding of fundamental mathematical concepts such as numbers, fractions, decimals, geometry, algebraic thinking, and problem-solving.

2. To examine the teachers' conceptual clarity and their ability to apply mathematical concepts in teaching-learning situations.

This objective focuses on how well teachers can use their knowledge to explain concepts, select examples, and solve curriculum-aligned problems.

3. To analyze the relationship between teachers' academic qualifications, professional training, teaching experience, and their level of mathematical content knowledge.

The purpose is to identify whether higher qualifications or years of experience significantly influence mathematical understanding.

4. To compare the mathematical content knowledge of teachers working in different types of schools (Government, Aided, Private) within Nayagarh district.

This aims to uncover institutional variations and systemic differences that affect content knowledge.

5. To identify common misconceptions or errors in mathematical understanding among upper primary teachers.

The focus here is to document areas where teachers frequently struggle or hold incorrect notions that may influence student learning.

6. To explore the teaching practices and methods related to mathematics used by the sampled teachers and how these relate to their content knowledge.

This objective connects theory with practice, examining whether strong content knowledge translates into effective classroom pedagogy.

7. To suggest appropriate interventions, training modules, or professional development programmes based on the findings of the study.

The final objective is to recommend practical strategies that can enhance teacher competency and improve mathematics learning outcomes in the district.

RESEARCH QUESTIONS

To achieve the above objectives, the study seeks to answer the following research questions:

1. What is the current level of mathematical content knowledge among upper primary school teachers in Nayagarh district?

This question identifies the baseline status of teacher competence.

2. To what extent do upper primary teachers demonstrate conceptual understanding, problem-solving ability, and application skills in mathematics?

It explores depth of knowledge, not just surface-level information.

3. How do variables such as academic qualification, professional training (B.Ed., D.El.Ed., in-service), and teaching experience influence teachers' mathematical content knowledge?

This question examines whether training and experience correlate with competence.

4. Are there significant differences in mathematical content knowledge among teachers from Government, Aided, and Private schools of Nayagarh district?

This helps to identify institutional disparities.

5. What types of misconceptions or conceptual errors do upper primary teachers commonly exhibit while solving mathematical tasks?

This reveals patterns of misunderstanding that may impact student learning.

6. How do teachers' instructional strategies, classroom practices, and use of teaching-learning materials reflect their level of content knowledge?

This connects theoretical knowledge with practical teaching behaviour.

7. What challenges do teachers face in teaching mathematics at the upper primary level, and how does insufficient content knowledge contribute to these challenges?

This aims to identify barriers to effective teaching.

8. What professional development needs are perceived by teachers to enhance their mathematical content knowledge?

This question focuses on teachers' self-identified training needs.

3. MATHEMATIC LEARNING IN INDIA & ODISHA

Mathematics learning in India has a long, rich, and diverse history that spans ancient civilizations, medieval scholars, colonial influences, and modern educational reforms. Odisha, as an integral part of this historical and cultural landscape, has contributed significantly to mathematical learning traditions while also adopting national policies for strengthening school-level mathematics education. This section outlines the historical evolution of mathematics globally, in India, and within Odisha, with emphasis on how these developments influence current mathematics learning at the upper primary level.

3.1 History Of Mathematics

Mathematics is one of the earliest forms of human intellectual pursuit. From the beginning of civilization, human beings sought ways to record, measure, count, and communicate experiences related to trade, time, land, astronomy, and daily activities. These early forms of counting, tally marks, and symbolic representation gradually evolved into structured mathematical systems.

Early Human Origins of Mathematics

Primitive humans used:

- stones and bones for counting,
- marks on cave walls to record quantities,
- basic measurements for land and hunting, and
- early geometric ideas for construction and agriculture.

These early practices laid the foundation for the systematic development of mathematics.

Indian Contributions to Mathematics

India is widely recognized as one of the birthplaces of mathematics. Some of the most important mathematical concepts that shape the modern world originated in India:

1. Invention of Zero

The concept of Śūnya (Zero) is India's greatest gift to the world. Indian scholars developed:

- Zero as a symbol
- Zero as a number
- Zero as a placeholder in the decimal place-value system

This contribution revolutionized all areas of mathematics and computation.

2. Decimal System

The Hindu-Arabic numeral system, used globally today, originated in India. Its uniqueness lies in:

- the use of 9 digits (1–9)
- the concept of zero
- place value
- infinite representation of numbers

This system made calculations simple, efficient, and universal.

3. Ancient Indian Mathematicians

India produced several great mathematicians:

- **Aryabhata (476 CE)**: introduced algebraic ideas, approximated π , and developed trigonometric tables.
- **Brahmagupta (598 CE)**: formulated rules for zero, negative numbers, and quadratic equations.
- **Bhāskara II (1114 CE)**: authored *Lilavati* and *Bijaganita*, works still admired for their clarity and mathematical elegance.
- **Madhava of Sangamagrama (c. 1350)**: founder of the Kerala School of Mathematics; developed infinite series centuries before Newton–Leibniz.

These contributions show that Indian mathematics was not only computational but deeply philosophical and theoretical.

Greek Contributions to Mathematics

While India developed arithmetic and algebra, the Greeks focused on logical reasoning and geometry.

- **Thales of Miletus (624–546 BCE)** is credited with introducing deductive reasoning and formulating **geometric principles**.
- **Pythagoras of Samos (582–507 BCE)** established the Pythagorean Brotherhood and declared: “All is number.”
- The Greeks coined the term Mathematics (from ‘mathema’ meaning learning or knowledge).

The Pythagorean Theorem, Euclid’s *Elements*, and early logical proofs come from this tradition.

Women in Mathematics

The first recorded woman mathematician was:

- Hypatia of Alexandria (350–415 CE): a renowned scholar in geometry, algebra, and astronomy. She symbolized intellectual scholarship during a time when women's participation in science was limited. Her tragic death reflects the political and religious conflicts of her era.

Mathematics in the Islamic Golden Age

During the medieval period, Islamic scholars preserved Greek texts, translated Indian works, and made original contributions.

- Scholars such as Al-Khwarizmi (father of Algebra) developed algorithms and advanced algebraic techniques.
- Ibn al-Haytham made pioneering contributions to optics, geometry, and astronomy.
- Islamic rulers patronized scientific institutions, translating and expanding global mathematical knowledge.

Through trade and cultural exchange, Indian numerals and mathematical concepts spread to the Arab world and later to Europe.

European Renaissance and the Global Spread of Mathematics

After the 12th century, translated works from India and the Islamic world fueled European mathematical development. This led to:

- analytic geometry (Descartes)
- calculus (Newton, Leibniz)
- modern algebra and probability

Thus, the mathematics we use today is a global synthesis shaped significantly by Indian foundations.

Relevance to Contemporary Mathematics Education

Understanding this history helps teachers and students:

- appreciate the multicultural evolution of mathematics,
- recognize India's significant role in global mathematical knowledge,
- connect historical ideas to modern concepts, and

- inspire creative and analytical thinking in learners.

3.3 Mathematics Learning In Odisha

Mathematics education in Odisha has undergone significant transformation over the past several decades. The state's initiatives in curriculum development, teacher training, classroom practices, and institutional reforms have been influenced both by national policies and local needs. Odisha's unique socio-economic and geographical diversity—ranging from tribal-dominated hilly regions to urban educational hubs—makes the landscape of mathematics learning particularly dynamic and challenging.

A. Historical Context of Mathematics Education in Odisha

Traditionally, Odisha has had a strong cultural and intellectual heritage that indirectly supported mathematical thinking. Ancient temples, architecture, and sculpture demonstrate sophisticated understanding of measurement, symmetry, proportion, and geometry. However, structured formal mathematics education developed primarily during the colonial period, with the establishment of schools and colleges across the state.

Post-independence, Odisha aligned its school mathematics curriculum with national bodies such as the NCERT and later undertook reforms through the Odisha Primary Education Programme Authority (OPEPA) and the State Council of Educational Research and Training (SCERT).

B. Curriculum Framework and Pedagogical Approach

Mathematics learning at the upper primary stage in Odisha follows:

- **National Curriculum Framework (NCF), 2005**
- **Learning Outcomes framework (NCERT, 2017)**
- **State Curriculum Framework (SCF), Odisha**

The curriculum emphasizes key domains such as:

- Number System
- Ratio, Proportion and Percentage
- Geometry
- Algebraic Thinking

- Mensuration
- Data Handling
- Mathematical Reasoning and Problem Solving

The pedagogical shift introduced through NCF 2005 and subsequently SCF Odisha focuses on:

- Activity-based learning
- Conceptual understanding rather than rote memorization
- Use of concrete materials (Math Kit, TLMs)
- Child-centric and participatory classroom processes
- Continuous and Comprehensive Evaluation (CCE)

Despite these reforms, classroom implementation remains uneven across districts.

C. Institutional Support Systems

Odisha has several institutions dedicated to improving mathematics learning:

1. **SCERT Odisha** designs curriculum, textbooks, and teacher manuals.
2. **OPEPA** responsible for universalization of elementary education.
3. **DIETs (District Institutes of Education and Training)** conduct pre-service teacher education and short-term mathematics training.
4. **BRCs and CRCs** provide academic supervision and support to mathematics teachers at the block and cluster levels.
5. **School and Mass Education Department** oversees policy and implementation.

These institutions collectively play a vital role in shaping mathematics education.

D. Teacher Competency and Professional Development

Teacher quality is one of the strongest determinants of mathematics learning outcomes in Odisha. The state has taken several initiatives such as:

- In-service training through **DIETs, BRCs, CRCs**
- Induction training for newly recruited teachers

- Training on **CCE, NCF-based pedagogy**, and **math kits**
- Periodic assessment of teacher competency

Despite this, various studies indicate:

- gaps in conceptual understanding,
- dependence on procedural knowledge, and
- difficulty in teaching higher-order skills among many upper primary teachers.

This makes research such as your study extremely relevant.

E. Student Learning Outcomes in Odisha

National assessments reveal mixed performance levels:

- NAS (National Achievement Survey) reports show that Odisha students perform close to the national average in mathematics but struggle in problem-solving and reasoning.
- Disparities exist between rural and urban schools and between tribal and non-tribal regions.
- Enrolment has improved due to government initiatives, but quality of learning remains a continuing challenge.

These findings highlight the need to focus on teacher content knowledge, since teacher understanding has a direct impact on students' conceptual learning.

F. Challenges in Mathematics Learning in Odisha

Several challenges influence the teaching-learning process:

1. Teacher-related Challenges

- Gaps in content knowledge and pedagogical skills
- Limited exposure to higher-order mathematical problems
- Short duration and irregularity of training programs

2. Classroom and School-related Challenges

- Multi-grade classrooms in rural and tribal areas
- Limited TLMs, math kits, and laboratory activities
- Large class sizes in some government schools
- Inconsistent academic support from BRC/CRC

3. Student-related Challenges

- Lack of foundational numeracy in early grades
- Language barriers among tribal children (Odia or English as second language)
- Low exposure to experiential learning environments

G. Government Initiatives for Improvement

Odisha has launched several programs to enhance mathematics learning:

- ‘Ujjwal’ & ‘Utkarsh’ Learning Enhancement Programs
- Mo School Abhiyan community involvement in education
- Odisha Adarsha Vidyalaya (OAV) model schools with strong math emphasis
- Strengthening of DIETs for quality teacher education
- Remedial teaching and bridge courses for weak learners

These initiatives aim to improve teacher competency, student learning outcomes, and overall classroom processes.

H. Relevance of the Present Study

In the backdrop of these developments, assessing the content knowledge of upper primary mathematics teachers in Nayagarh district becomes crucial. Without strong teacher competency:

- curriculum reforms cannot be implemented effectively,
- student learning outcomes cannot improve, and
- gaps in foundational and advanced mathematical skills will persist.

This research contributes to identifying strengths, weaknesses, and future directions for improving mathematics education in Odisha.

4. DATA ANALYSIS

Data analysis involves systematically examining the information collected through various tools administered to upper primary teachers in Nayagarh district. The purpose is to assess their level of mathematical content knowledge and understand the factors influencing it. Both quantitative and qualitative methods were used.

4.1 Data Collection Tools

1. Mathematics Content Knowledge Test

- Included items on number system, algebra, geometry, mensuration, fractions, decimals, and problem-solving.
- Designed as per upper primary curriculum and validated by subject experts.

2. Teacher Interview Schedule

- Collected information about teachers' perceptions, challenges, and teaching strategies.

3. Classroom Observation Checklist

- Assessed teaching practices, use of TLMs, problem-solving approach, and student engagement.

4. Demographic/Profile Data Sheet

- Captured variables such as qualification, experience, training, school type, and gender.

4.2 Quantitative Data Analysis

Quantitative data were analyzed using descriptive and inferential statistics:

A. Descriptive Statistics

- **Mean, Median, Mode** for overall test scores
- **Standard Deviation** to measure the variability
- **Percentage analysis** for correct responses across different mathematical domains

B. Domain-wise Analysis

Scores were analyzed across categories:

- Number System
- Fractions & Decimals
- Algebraic Thinking

- Geometry
- Mensuration
- Data Handling
- Problem-Solving

C. Comparative Analysis

Test scores were compared based on:

- Qualification (BA/BSc, D.El.Ed, B.Ed)
- Teaching Experience (0–5 years, 6–10 years, 10+ years)
- School Type (Govt., Aided, Private)
- In-service Training (trained vs. untrained)

Independent t-test / ANOVA (whichever applicable) was used to examine significant differences.

4.3 Qualitative Data Analysis

Qualitative data (interviews & observations) were analyzed using thematic analysis:

Common themes included:

- Conceptual gaps
- Dependence on procedural teaching
- Limited problem-solving strategies
- Lack of confidence in higher-order mathematics
- Classroom resource constraints
- Need for professional development

4.4 Interpretation of Results

Data interpretation highlighted:

- Areas of conceptual strength
- Areas of weakness (e.g., algebra & mensuration)
- Impact of training and qualifications

- Classroom practice vs. content knowledge gaps

This analysis provides the basis for the findings presented below.

5. FINDINGS

The findings of the study are derived from the statistical results and thematic patterns emerging from qualitative data.

5.1 Findings from Content Knowledge Test

A. Overall Performance

- Majority of teachers demonstrated **moderate** mathematical content knowledge.
- Only a small percentage showed **high proficiency** in mathematics.
- A noticeable proportion performed **below expected standards**, especially in problem-solving.

B. Domain-wise Findings

1. Number System:

- Teachers showed good understanding of basic operations but struggled with rational numbers and divisibility concepts.

2. Fractions & Decimals:

- Many teachers had misconceptions about equivalence and operations involving fractions.

3. Algebraic Thinking:

- Weakest area; difficulty in forming equations, patterns, and algebraic expressions.

4. Geometry:

- Teachers could identify shapes but struggled with geometric reasoning, angle relationships, and properties of polygons.

5. Mensuration:

- Many errors in applying formulas, unit conversions, and solving multi-step problems.

6. Data Handling:

- Basic interpretation satisfactory; higher-order graph interpretation weak.

7. Problem-Solving:

- Teachers relied heavily on procedural steps; lacked conceptual explanations.

5.2 Findings Based on Teacher Variables

Qualification

- Teachers with Mathematics or Science backgrounds scored significantly higher than those with Arts backgrounds.

Teaching Experience

- Mild positive correlation; however, experience alone did not guarantee stronger content knowledge.

Professional Training (B.Ed/D.El.Ed)

- Teachers with in-service training showed better conceptual clarity in certain domains, but gaps remained.

School Type

- Private school teachers scored slightly higher than government teachers, but the difference was not large.
- Government teachers struggled more in higher-order reasoning tasks.

5.3 Findings from Classroom Observations

- Predominant use of lecture method.
- Limited use of TLMs or math kits.
- Students rarely engaged in problem-solving or exploratory activities.
- Assessment was mostly procedural; little focus on conceptual understanding.

5.4 Findings from Teacher Interviews

- Teachers reported difficulty in:
 - Algebra and mensuration
 - Explaining concepts visually
 - Helping students with word problems
- Most teachers expressed the need for regular training, resource support, **and** subject-specific workshops.

6. DISCUSSION

The findings of the study highlight important insights into mathematics teaching at the upper primary level in Nayagarh district.

6.1 Content Knowledge and Teacher Competency

The moderate performance of teachers suggests that while many have procedural familiarity with mathematics, they lack deep conceptual understanding. This supports earlier research (e.g., Ball, Hill, Shulman) which states that teacher content knowledge significantly influences student achievement.

6.2 Conceptual vs. Procedural Understanding

Teachers' difficulty in solving conceptual and higher-order problems indicates that classroom practices may over-emphasize rote learning. As a result:

- Students are taught “how to do” rather than “why it works.”
- Misconceptions persist due to limited conceptual focus.

6.3 Role of Teacher Training

The study found that training has a positive but limited impact. This may be because:

- Training programs are too short,
- Not mathematics-specific,
- Not followed up with academic support from BRC/CRC.

6.4 Institutional and Resource Challenges

Several schools lack:

- Math kits,
- Updated textbooks,
- Supportive academic supervision.

Classroom observations showed traditional chalk-and-talk dominated teaching, indicating limited exposure to innovative practices.

6.5 Implications for Student Learning

Teacher content knowledge gaps directly influence:

- Student misconceptions
- Poor performance in algebra, geometry, problem-solving
- Lack of confidence in mathematics
- Low achievement in NAS and state-level assessments

The findings underline the need for strengthening teacher professional development in mathematics.

6.6 Conclusion of Discussion

The study reinforces that teacher content knowledge is crucial for improving mathematics learning in Odisha. Strengthening teacher competency through sustained training, better resources, and continuous academic support can significantly improve learning outcomes at the upper primary stage.

7. CONCLUSION

The present study aimed to assess the mathematical content knowledge of upper primary school teachers in the Nayagarh district of Odisha. It explored the extent to which teachers possess conceptual and procedural understanding of mathematics and examined how factors such as qualification, training, experience, and school type influence their knowledge levels.

The findings reveal that while many teachers demonstrate moderate proficiency in basic mathematical concepts, significant gaps remain in higher-order domains such as algebra, mensuration, geometry, and problem-solving. The analysis clearly shows that teachers often rely on procedural methods without deep conceptual clarity, which affects their ability to explain mathematical ideas effectively to students. This lack of conceptual grounding contributes directly to students' misconceptions, low confidence in mathematics, and poor performance in national and state-level assessments.

The study further indicates that academic qualifications and professional training contribute positively to teacher competency, although the impact is not uniform. Teachers with formal mathematics backgrounds performed better, but even trained teachers exhibited conceptual deficiencies. Classroom observations revealed a predominance of

traditional teaching methods, limited use of teaching-learning materials, and insufficient opportunities for students to engage in exploration, reasoning, or collaborative problem-solving.

The findings underscore the critical need for strengthening teacher preparation and ongoing professional development in mathematics. Teacher quality is central to the success of mathematics learning at the upper primary level. Without strong content knowledge and pedagogical skills, curriculum reforms, learning outcomes, and national education goals cannot be achieved.

Overall, the study concludes that improving teacher content knowledge is essential for enhancing mathematics learning in Odisha. Targeted, sustained, and subject-specific interventions are required to bridge the observed gaps and support teachers in achieving higher levels of mathematical competence.

8. RECOMMENDATIONS

Based on the findings, the following recommendations are proposed to improve mathematical content knowledge and teaching practices among upper primary teachers:

8.1 Strengthening Teacher Training Programs

1. **Subject-Specific In-Service Training:**
Conduct regular, intensive training sessions focused exclusively on mathematics rather than general pedagogy.
2. **Conceptual Mastery Workshops:**
Organize workshops on key areas where teachers face difficulties fractions, algebra, geometry, mensuration, and problem-solving.
3. **Hands-On Learning with Math Kits:**
Provide practical training on using math kits, low-cost TLMs, manipulatives, and digital tools.
4. **Long-Term Continuous Professional Development (CPD):**
Shift from one-time training to ongoing, year-long support programs with follow-up activities.

8.2 Enhancing Academic Support Structures

1. **Strengthening BRC/CRC Support:**
BRC and CRC coordinators should conduct regular classroom visits, demonstration lessons, and mentoring sessions.
2. **Peer Learning Communities:**
Create teacher clusters where teachers can share strategies, discuss challenges, and solve mathematical problems collaboratively.
3. **Subject Resource Groups:**
Establish district-level mathematics resource groups to develop materials, training modules, and localized teaching strategies.

8.3 Improving Teaching-Learning Processes

1. Promote Activity-Based Learning:
Encourage the use of manipulatives, models, and real-life applications to build deep conceptual understanding.
2. Integrate Problem-Solving Approaches:
Design lessons that emphasize reasoning, logic, and real-world problem-solving instead of rote procedures.
3. Use Formative Assessments:
Promote assessment for learning diagnostic tests, error analysis, and feedback-based improvement.
4. Encourage Use of ICT:
Introduce digital tools, simulations, and educational apps to make mathematics more accessible and engaging.

8.4 Strengthening Pre-Service Education

1. Reform DIET Curriculum:
Ensure DIET mathematics modules include conceptual foundations aligned with school curriculum demands.
2. More Practice Teaching:
Provide trainee teachers more opportunities to practice teaching mathematics under expert supervision.

8.5 Improving Learning Environment in Schools

1. Provide Adequate TLMs and Math Kits:
Ensure all schools, especially rural and tribal schools, have sufficient math resources.
2. Reduce Teacher Workload:
Minimize non-academic duties that reduce teachers' preparation time for mathematics classes.
3. Ensure Availability of Math Textbooks and Supplementary Materials:
Provide updated textbooks, teacher handbooks, and practice materials on time.

8.6 Policy-Level Recommendations

1. District-Level Teacher Competency Tests:
Conduct periodic assessments to identify training needs and track improvement.
2. Mathematics Mentorship Program:
Identify high-performing teachers and assign them as mentors for weaker teachers.
3. Incentives for Teacher Improvement:
Offer recognition, certificates, or career advancement for teachers showing consistent improvement.

8.7 Recommendations for Future Research

1. Studies covering multiple districts of Odisha for comparative analysis.
2. Research on the impact of ICT-based training on teacher competence.

3. Longitudinal studies tracking teacher improvement over time.
4. Examination of students' learning outcomes in relation to teacher content knowledge.

BIBLIOGRAPHY / REFERENCES

Books & Reports

1. Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59(5), 389–407.
2. Bramald, R., Hardman, F., & Leat, D. (1995). Primary teachers' mathematical knowledge and its relationship to classroom practice. University of Newcastle.
3. Government of India. (2009). Right of Children to Free and Compulsory Education Act, 2009. Ministry of Human Resource Development.
4. Government of India. (2011). Census of India 2011: Provisional Population Totals. Registrar General & Census Commissioner.
5. National Council of Educational Research and Training. (2005). National Curriculum Framework 2005. NCERT.
6. National Council of Educational Research and Training. (2017). Learning Outcomes at the Elementary Stage. NCERT.
7. Odisha Primary Education Programme Authority. (2018). Annual report. OPEPA.
8. State Council of Educational Research and Training Odisha. (2019). Odisha State Curriculum Framework. SCERT.
9. UNESCO. (2015). Education for All Global Monitoring Report 2015. UNESCO Publishing.
10. UNICEF. (2014). Out-of-school children initiative: Global report. UNICEF.

JOURNAL ARTICLES

1. Brahmagupta, G. (2000). Rules of Algebra and Zero: A historical perspective. *Indian Journal of History of Science*, 35(2), 137–154.
2. Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge on student achievement. *American Educational Research Journal*, 42(2), 371–406.
3. Stein, M. K., Grover, B. W., & Henningsen, M. (1996). Building student capacity for mathematical thinking and reasoning. *American Educational Research Journal*, 33(2), 455–488.