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Efficacy of Concrete Representational Abstract Approach in Early Grade Mathematics Education

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Abstract

This study assessed the effectiveness of the Concrete Representational Abstract (CRA) approach in mathematics education in Kalahandi district, Odisha, characterized by socio-economic diversity and educational obstacles. Utilizing a descriptive survey method involving 20 schools, 357 class III students, 40 math teachers, and 20 Head Masters, data was collected. Results indicated positive influences on math learning outcomes post-CRA implementation, particularly in grasping arithmetic concepts. However, challenges persist in teaching complex arithmetic, integrating textbooks with workbooks, and leveraging technology effectively. Division in understanding and applying arithmetic operations remains a hurdle. To address these, strategies like improved teacher training, curriculum alignment, tech integration, diverse learning materials, and sustained support mechanisms are suggested. Despite obstacles, the CRA approach exhibits potential in enhancing math education in challenging settings, underscoring the need for ongoing support to ensure sustained positive impact and cater to diverse learning needs in resource-limited contexts.

Keywords: *Concrete-Representational-Abstract approach, Mathematics education, Technology integration, Simplifying arithmetic operations*

Introduction

The Concrete Representational Abstract (CRA) approach has gained considerable attention in educational contexts worldwide due to its efficacy in teaching mathematics (NAMP, 2008; Kaffar & Miller, 2011; Scruggs & Mastropieri, 2013; Hinton & Flores, 2019; Nugroho & Jailani, 2019). The National Education Policy (NEP) 2020 in India has indeed given paramount importance to a constructive approach in education. The NEP 2020 emphasizes a shift from rote learning to a more holistic and comprehensive learning methodology. NEP

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2020's focus on a constructive approach aims to revolutionize the Indian education system, making it more inclusive, adaptable, and geared towards nurturing well-rounded individuals equipped with 21st-century skills. Particularly in government schools, where diverse learning needs and resource constraints often prevail, exploring innovative pedagogical methods becomes crucial (RTI, 2023).

The CRA approach, rooted in cognitive science and constructivist theories of learning, emphasizes a progressive method to teach mathematical concepts (Brune, 1960; Piaget,1970; Vygotsky, 1978; Santrock, 2007; Strickland, 2016). It involves three distinct stages – the *concrete stage*, where students engage with physical objects or manipulatives to understand mathematical ideas; the *representational stage* depicts visual representations like diagrams or drawings and the *abstract stage*, whereas students work with numerical symbols to solve problems (Kamii et al., 2001; Siegler et al., 2010; Strickland, 2016). This approach aims to scaffold learning, ensuring students grasp mathematical concepts thoroughly before moving to abstract representations, thus promoting deeper understanding and long-term retention (Dixon & Carnine, 1993; Pressley et al., 1996; Larkin, 2001; Bouck et al., 2017).

This paper investigates the efficacy of the Concrete Representational Abstract approach in the context of government schools situated in the Kalahandi district of Odisha, India. The Kalahandi district, known for its socio-economic diversity and rural landscape, provides a unique setting to evaluate the implementation and impact of educational strategies, especially in subjects like mathematics. The implementation of innovative teaching methods like CRA holds significant promise, especially in regions such as Kalahandi, where educational disparities and access to quality learning resources are prevalent. Government schools often face challenges concerning student engagement, resource availability, and effective pedagogical strategies in mathematics education (Henningsen & Stein, 1996; Zaidi & Ali, 2019).

Hence, assessing the effectiveness of CRA in this context is pivotal, as it could potentially address these challenges and enhance mathematics learning outcomes among students. Previous research on the CRA approach in diverse educational settings has demonstrated positive outcomes. Studies by Clements and Sarama (2007) and Van de Walle (2006) highlight the effectiveness of CRA in improving students' mathematical understanding and problem-solving skills. Moreover, research conducted by Piaget (1970) and Vygotsky (1978) supports the theoretical framework underlying CRA, emphasizing the importance of hands-on experiences and scaffolding in learning mathematical concepts.

However, while there is substantial literature supporting the effectiveness of CRA (Van de Walle, 2006; Clements & Sarama, 2007; Santrock, 2007; Flores, 2010; Kaffar & Miller, 2011; Hinton & Flores, 2019) its application and impact specifically in government schools in Odisha in general andtribal dominated district like Kalahandi in particular have not been extensively studied. It's essential to comprehend how this method corresponds to the socio-economic and educational framework of the area. This understanding is pivotal in customizing educational strategies that specifically address the distinctive requirements of student’s achievement in mathematic learning.

This study aims to fill this gap in the literature by examining the efficacy of the CRA approach in enhancing mathematics learning outcomes among students in government schools in Kalahandi district. Through an evaluation of the application of CRA, this study offers empirical evidence regarding the practicality and efficiency of the CRA approach within this particular educational setting. Hence, implementation of innovative teaching methodologies like the Concrete Representational Abstract approach in government schools, particularly in regions like Kalahandi, holds significant promise for improving mathematics education.

This study seeks to delve into the practical implications and effectiveness of the CRA approach in this context. Besides, it aims to provide insights that can inform educational policies and practices to better serve students in government schools with special reference to following specific objectives.

Objectives

1. To examine the utilization and effectiveness of facilities/activities in facilitating the CRA approach in mathematics learning at school level.
2. To assess the impact of the Concrete-Representational-Abstract (CRA) approach on students' mathematics performance in Kalahandi District schools.
3. To identify obstacles faced by teachers in implementing the CRA approach for teaching basic arithmetic operations.

Methodology

The study used a descriptive survey method to comprehensively analyse the obstacles in implementation of CRA approach in teaching arithmetic. The study involved a total of 357 students from classIIIacross the 20 selected schools and 40 mathematics teachers participated in the survey. Besides, the survey included 20 Head Masters representing the sampled schools of Kalahandi district of Odisha.

The teachers have gone through FLN training using CRA approach under DIET, Kalahandi. Schools were supplies with Ganita Kalika Andolana (GKA) resource material for mathematics learning. This study used multiple tools for data collection, such as observation schedules, questionnaires for mathematics teachers and students and an Arithmetic Test Battery. Students' achievement in basic arithmetic operations-*Addition, Subtraction, Multiplication, and Division*was evaluated using an Arithmetic Test Battery. Both pre-test and post-test assessments were conducted to measure students' progress and achievement.

An Observation Schedule for Head Master was designed to observe and record specific aspects related in classroom transaction. Questionnaire for Mathematics Teachers was to gather insights into the perceptions, challenges faceand strategies employed by mathematics teachers in teaching arithmetic operations. The study used both descriptive and inferential statisticsto interpret the results.

Results and Discussion

Use of Facilities/activities to facilitate CRA approach

Concrete materials and appropriate facilities play an integral role in the success of the Concrete-Representational-Abstract (CRA) approach in mathematics education. These resources serve as tangible tools that enable students to grasp abstract mathematical concepts by starting with hands-on, concrete materials. Access to facilities equipped with diverse manipulatives with the opportunity to engage actively in the learning process. These materials allow for direct manipulation and visual representation of mathematical concepts, facilitating a deeper understanding before transitioning to representational and abstract levels.

Table 1. Use of Facilities/activities to facilitate CRA approach

Facilities	NS	S	G	VG	E	Mean	SD
Wall Activities	1	17	10	10	2	2.88	0.99
Floor Activities	0	14	16	8	2	2.95	0.88
Learning Corner	0	13	12	12	3	3.13	0.97
Attractive Blackboard	4	9	15	12	0	2.88	0.97
Ground Level Black Board	7	10	9	14	0	2.75	1.13
TLM Corner	4	8	19	7	2	2.88	0.99
Digital Board	34	4	0	2	0	1.25	0.71
Sound System	22	7	3	8	0	1.93	1.21
Bench and Desk Facilities	33	2	1	4	0	1.40	0.96
NS: Not Satisfactory, S: Satisfactory, G: Good, VG: Very Good, E-Excellent							

Table 1 summarised the effectiveness of facilities for implementing the Concrete-Representational-Abstract (CRA) approach in teaching mathematics at the school level. Key findings reveal that certain facilities, such as "Floor Activities" (mean: 2.95), "Learning Corner" (mean: 3.13), and "Wall Activities" (mean: 2.88), are utilized well and meet or exceed teacher expectations, contributing positively to math education. Conversely, "Digital Board" (mean: 1.25), "Sound System" (mean: 1.93), and "Bench and Desk Facilities" (mean: 1.40) received notably lower ratings, indicating a pressing need for improvement to better align with student expectations.

These lower ratings suggest a requirement for enhanced utilization, particularly in ICT-based resources, highlighting the necessity for teacher training and support. The lower standard deviations, notably for the "Digital Board" (SD: 0.71), indicate greater consensus among respondents, pointing towards underutilization across most schools. Overall, improving specific facilities, particularly ICT resources, and providing comprehensive teacher training can significantly enhance mathematics education through the CRA approach.

Table 2. Observation on Learning Activities during CRA implementation

Learning Activities during CRA implementation	S	G	VG	O	Mean	SD
Use of CRA Kit	9	18	11	2	2.15	0.83
Joyful learning and spontaneous involvement	8	21	10	1	2.10	0.74
Use of concrete materials for concept clarification	5	24	11	0	2.15	0.62
Use of Graphical representation after use of concrete material for doubt clarification	19	14	7	0	1.70	0.76
Derive abstract from graphical representation to solve the math problems	12	24	4	0	1.80	0.61
Guidance of teacher	7	18	13	2	2.25	0.81
Correction works by teachers on math problem	8	19	11	2	2.18	0.81
S: Satisfactory, GV: Very Good, G: Good, O-Outstanding						

Analysis of head teachers' observations on math teachers implementing the CRA (Concrete-Representational-Abstract) approach presented in table 2 indicated moderate performance overall (close to 2, denoting 'Good'). The highest mean scores were for "Guidance of teacher" (2.25) and "correction work by teachers on math problems" (2.18), suggesting effective support provided to students during learning activities.

However, certain areas need immediate attention. Scores for "Use of Graphical representation for doubt clarification" (1.70) and "Derive abstract to solve math problems" (1.80) were lower, indicating the necessity for better graphical representations to address student doubts and improved strategies for transitioning from concrete to abstract problem-solving.

Although teachers show progress in areas like using concrete materials and involving students spontaneously, there's room for improvement. Focusing on enhancing graphical representations, providing better guidance in abstract problem-solving, and maximizing the GKA Kit's effectiveness can significantly improve the comprehensive and engaging nature of math learning through the CRA approach.

Performance of Students in Mathematics

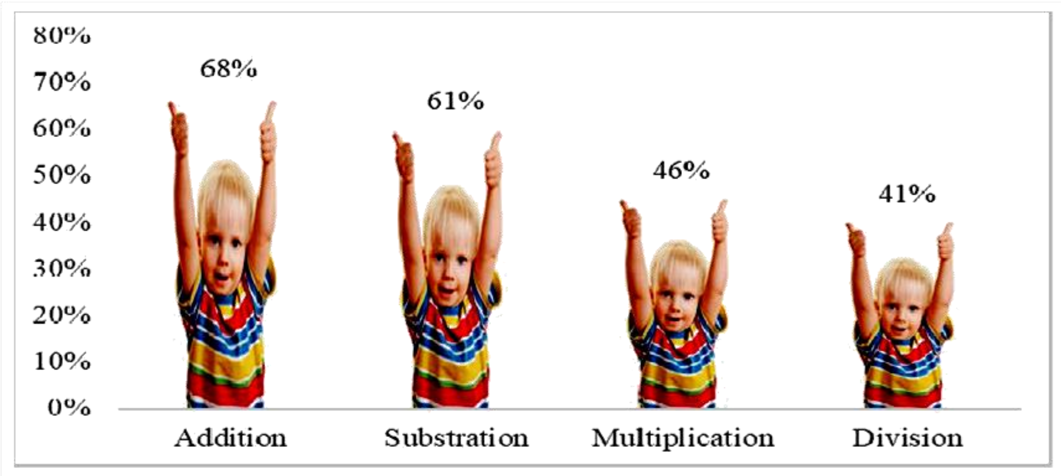
The analysis of students' mathematics performance after the implementation of the CRA (Concrete-Representational-Abstract) approach revealed encouraging results. The CRA method, designed to enhance conceptual understanding through progressive learning stages, has demonstrated its efficacy in improving students' overall mathematical abilities in the selected schools of Kalahandi District. To assess students' performance, the study has categorized their scores into different grade criteria based on the corresponding percentage of marks.

Table 3. Performance of Students in Four Basic Operations in Mathematics

Classification		**Very Good**	**Good**	**Average (Satisfactory)**	**Below Average**	**Poor**	**Desirable Performance**
Corresponding Marks		**81-100**	**61-80**	**41-60**	**21-40**	**Up to 20**	
Addition	N	67	83	95	94	18	68.63%
	%	18.77	23.25	26.61	26.33	5.04	
Subtraction	N	56	76	89	101	35	61.9%
	%	15.69	21.29	24.93	28.29	9.8	
Multiplication	N	0	62	103	103	89	46.22%
	%	0	17.37	28.85	28.85	24.93	
Division	N	0	18	129	107	103	41.18%
	%	0	5.04	36.13	29.97	28.85	

The analysis of students' proficiency in basic mathematical operations presented in table 3 revealed varying levels of competency across addition, subtraction, multiplication, and division. Notably, the majority of students exhibit a strong understanding of addition (68.63%) and subtraction (61.9%), showcasing a commendable grasp of these operations. However, the proficiency percentages take a noticeable downturn when considering multiplication, with only 46.22% of students displaying competence, followed by an even lower proficiency in division at 41.18%. This declining trend suggests that while addition and subtraction are more comprehensively understood, a considerable portion of students face challenges in mastering multiplication and division. Consequently, addressing these challenges through tailored teaching methodologies and additional support could significantly benefit students' overall mathematical abilities.

The figure is graphically presented in Figure 1.



[Fig.1 Percentage of Students Success in Four Basic Operations in Mathematics]

Moreover, a t-test was utilized to investigate the potential statistical disparity in students' mathematical performance between their pre-test and post-test scores. The study yielded specific findings regarding this comparison.

Table4. Difference in Pre-Test and Post-Test Scores (Total Marks=100)

Test	Mean	SD	t	Sig.
Pre-Test Score	54.08	24.13	8.97	0.001
Post-Test Score	68.87	19.69		

As observed from table 4 reflected the difference in pre-test and post test score of students in mathematics. The adoption of the Concrete-Representational-Abstract (CRA) approach in teaching mathematics has yielded a notable and statistically significant improvement in student learning outcomes, as indicated by the test results. The transition from a pre-test mean of 54.08 to a post-test mean of 68.87 demonstrates a substantial enhancement in students' understanding and proficiency in mathematical concepts.

With a t-value of 8.97 and a significance level of 0.001, the evidence strongly supports the efficacy of the CRA method in facilitating enhanced comprehension and application of mathematical principles. This outcome underscores the effectiveness of integrating concrete, representational, and abstract teaching strategies, affirming their pivotal role in advancing students' mathematical skills and comprehension levels significantly.

Obstacles in CRA implementation

The study explores obstacles in implementation of CRA approach in classroom setting and it comes out with a few interesting findings as presented in table 5.

Table5. Teachers Perception on Obstacles in CRA implementation

Obstacles in CRA implementation (N=40)	Basic Arithmetic Operations			
	Addition	Subtraction	Multiplication	Division
Understanding	10.00	17.50	30.00	40.00
Application	20.00	27.50	30.00	32.50
Simplification	7.50	12.50	22.50	22.50
Presentation	10.00	20.00	22.50	32.50
Self-Learning	15.00	27.50	47.50	55.00
Co-Learning	10.00	17.50	22.50	32.50
Book Work	10.00	30.00	47.50	57.50
Book Integration	15.00	27.50	35.00	45.00
Assessment	15.00	30.00	37.50	25.00
Planning	5.00	7.50	10.00	15.00

Teachers using the Classroom Action Research (CRA) approach in mathematics encounter varying challenges. Division stands out as the most difficult operation for students to understand (40.00), while Subtraction (27.50) and Division (32.50) pose challenges when applying the CRA method. Simplifying concepts shares the challenges between Multiplication and Division (22.50), while Addition (7.50) and Subtraction (12.50) are less problematic. Division (55.00) presents significant hurdles in self-directed learning, followed by Multiplication (47.50) and Subtraction (27.50).

Division (57.50) and Multiplication (47.50) encounter substantial challenges when teaching through book work, whereas Addition (10.00) faces fewer obstacles. Planning lessons are less complicated for Addition (5.00) and Subtraction (7.50), while Multiplication (10.00) and Division (15.00) pose manageable challenges. Similarly, assessment proves less challenging for Addition (15.00) and Subtraction (30.00), while Multiplication (37.50) requires more attention, and Division (25.00) demands further quality maintenance.

From the above discussion, it is revealed that;

- Across various categories, it is evident that certain arithmetic operations consistently pose higher levels of difficulty for teachers and students alike. Notably, division emerges as a recurring obstacle in almost every aspect of CRA implementation. Teachers find that students struggle the most with understanding division, applying division concepts, simplifying division-related problems, and even self-learning division topics. Additionally, maintaining teaching quality and integrating division into textbook-based instruction are perceived as particularly challenging tasks.
- Multiplication also presents substantial challenges, especially when it comes to self-learning and book work scenarios. This suggests that students might encounter difficulties when attempting to independently grasp multiplication concepts or when working on exercises from textbooks.
- On the other hand, addition appears to be the least problematic operation in most categories, indicating that students tend to find addition concepts more accessible to understand, apply, and simplify. However, it's worth noting that even in these cases, teachers still encounter certain obstacles, albeit to a lesser extent.
- Subtraction's perceived difficulty varies across categories, but it generally falls in the middle of the spectrum. While it is not as consistently challenging as division or multiplication, teachers still need to address hurdles related to teaching, application, and integration of subtraction concepts.
- Planning and co-learning activities seem to have relatively lower levels of difficulty across all arithmetic operations. This implies that teacher's find it more manageable to incorporate the CRA approach when structuring lessons or facilitating collaborative learning experiences.

Further, analysis of the data regarding problems encountered during the integration of mathematics textbooks with workbooks at the elementary level reveals several noteworthy trends. The challenges identified encompass various dimensions of the educational process, shedding light on areas where improvements are essential for an effective learning experience.

Table 6. Problem related to integration of books with workbook

Problems while integration of books with workbook of mathematics	N	%
Knowledge:		
Misalignment of content between textbook and workbook.	14	35
Inadequate explanation of concepts in the textbook, leading to confusion.	18	45
Skills:		
Sudden increase in difficulty level between textbook and workbook.	22	55
Lack of variety in question types, not addressing diverse skills.	18	45
Application:		
Limited practical application of concepts in workbook exercises.	18	45
Contexts in workbook exercises not relatable or relevant to students.	12	30
Practices:		
Insufficient practice exercises in the workbook.	12	30
Unbalanced emphasis on repetition without critical thinking activities.	14	35
Additional Challenges:		
Lack of clear guidelines for self-assessment or teacher-led assessment.	7	17.5
Teachers not provided with proper guidance for integrating workbook activities.	7	17.5
Potential disparities in technology integration and access to digital resources.	9	22.5

The analysis of challenges in integrating mathematics textbooks with workbooks at the elementary level presented in table 6 reveals crucial areas for improvement. Concerns include content misalignment (35%), inadequate explanations (45%), and sudden difficulty spikes (55%), affecting students' understanding. Lack of diverse question types (45%) hampers varied assessments, while limited practical application opportunities (45%) hinder real-world relevance. Workbook contexts perceived as unrelated (30%) underscore the importance of relatable scenarios. Instructional challenges encompass insufficient practice exercises (30%) and an overemphasis on repetition (35%) rather than critical thinking activities. Clear assessment guidelines (17.5%) and teacher guidance (17.5%) are needed for effective feedback and support. Disparities in technology integration (22.5%) highlight the importance of equitable resource access.

In nutshell, these insights from the data analysis collectively underline the multifaceted nature of challenges in integrating mathematics textbooks with workbooks at the elementary level. Addressing these issues requires a holistic approach that involves curriculum alignment, pedagogical strategies, practical application, and equitable resource distribution. By acknowledging and acting upon these challenges, educators and curriculum designers can create a more cohesive and effective learning environment for elementary students.

Recommendations

The study recommends a multifaceted approach to enhance the implementation of the Concrete-Representational-Abstract (CRA) method in elementary mathematics education. First, it emphasizes specialized training programs for teachers, focusing on overcoming challenges related to teaching complex arithmetic operations like multiplication and division. Additionally, it suggests a thorough review of curricular materials to ensure alignment, coherence, and relevance to bolster students' comprehension of mathematical concepts.

Bridging the digital gap through equitable access to technology and resources is also proposed to create an interactive learning atmosphere in line with the CRA method. Moreover, advocating for diverse learning materials catering to various learning styles and abilities aims to foster inclusivity in mathematics education.

Finally, establishing continuous monitoring, evaluation, and support systems for teachers implementing the CRA approach intends to facilitate ongoing improvement and adaptation, effectively addressing emerging challenges and evolving educational needs.

Conclusion

The study underscores the efficacy of the Concrete-Representational-Abstract (CRA) approach in enhancing mathematics learning outcomes in government schools within the Kalahandi district of Odisha, India. Through a comprehensive assessment of the CRA implementation, it is evident that this pedagogical strategy significantly improves students' mathematical proficiency and understanding. The findings reveal a notable positive shift in student performance, evident from the pre-test to post-test assessments. The approach has proven instrumental in scaffolding learning, catering to diverse learning needs, and addressing educational disparities prevalent in the region. However, challenges persist, particularly in understanding complex arithmetic operations, aligning textbooks with workbooks, and leveraging technology effectively. Despite these challenges, the study emphasizes the substantial promise of the CRA method in enhancing mathematics education in such resource-constrained settings, emphasizing the need for continual support and tailored interventions to sustain and further enhance its impact.

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