

# The Effectiveness of the Concrete, Pictorial, and Abstract (CPA) Approach in Numeracy Learning for Prospective Students from Central Papua

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## Abstract

Motivated by low numeracy among Papuan children preparing for university, this study examined the effectiveness of the Concrete–Pictorial–Abstract (CPA) approach within the Holistic Academic Readiness Preparation Program (HARPP). A mixed-methods descriptive design combined quantitative measures (an initial diagnostic test and four formative assessments) with qualitative data (classroom observations and semi-structured interviews). Participants were prospective Papuan university students engaged in HARPP interventions that applied CPA consistently and used culturally adapted materials and locally meaningful examples. Quantitative results demonstrated substantial gains: arithmetic operations improved by 75–95% and geometry (Cartesian coordinates) by 78–92.5%. Qualitative findings corroborated these outcomes; students reported increased confidence, reduced anxiety, clearer conceptual understanding, and easier transitions from concrete manipulatives to pictorial representations and symbolic notation. Instructors noted improved student engagement and more effective formative feedback cycles. The study's novelty lies in embedding the CPA model within Papuan cultural contexts and addressing learners' unique linguistic and experiential backgrounds while maintaining instructional fidelity. Recommendations include wider implementation of CPA across preparatory programs, curriculum development emphasizing real-world contexts, targeted teacher professional development, and longitudinal research on retention and transfer to higher-level mathematics. Policy implications suggest integrating CPA-informed modules into national readiness programs to reduce equity gaps and improve university preparation outcomes for Papuan students.

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## Introduction

The main pillars of a nation's competitiveness are education, science, and innovation. Education plays a crucial role in developing the nation's next generation and is a solution to overcoming poverty, ignorance, unemployment, and lagging behind other nations. (Abdillah, 2024) As a primary platform for enhancing education, knowledge, and innovation, universities play a crucial role in developing highly competitive human resources. This role is highly strategic in driving development progress in various fields, including economics, social sciences, culture, and technology. (Sahrin et al., 2022). Universities aim not only to provide formal education but also to integrate the values of innovation, creativity, entrepreneurship, and divinity so that their graduates are able to face global challenges. In accordance with Law No. 22 of 1961, universities are scientific institutions tasked with providing education and teaching that can advance the Indonesian nation. (Humiaty & Budiarti, 2020).

When entering higher education, it is very important for every prospective student to have thorough preparation to help them be able to undergo higher education with in-depth knowledge and provide new innovations. (Faiz Firjatullah et al., 2023) The Program for International Student Assessment (PISA) internationally measures the abilities of children aged 15-17, including knowledge and skills in reading, mathematics, and science, to meet real-life challenges. According to the official PISA 2022 report, out of 81 countries participating in the program, Indonesia ranked 59th in reading literacy, 68th in mathematics, and 68th in science. (Solihin et al., 2024) This data information shows that Indonesia still faces significant challenges in improving the quality of education, particularly in the areas of literacy, numeracy, and science. This task is a challenge that academics must complete, considering that literacy and numeracy are fundamental skills that are crucial for Indonesian children to face the rapid development of the times. (Darwanto et al., 2021).

The 2023 national assessment results show varying results in numeracy and literacy skills across Indonesia. Papua remains at a level that requires significant intervention. As an integral part of Indonesia, Papua frequently faces geographical, social, and economic challenges, resulting in a lag in education, science, and innovation. (Primanda & Oktora, 2024) In general, Papuan children often face difficulties in learning numeracy and literacy, both due to limited educational resources and cultural differences that influence how they access and understand educational materials. Factors such as limited access to educational facilities and infrastructure, a shortage of competent teachers, and the influence of local culture that has not been fully integrated with the national education curriculum are the main causes. (Bawor & Ahmad, 2023) This situation creates an academic gap that directly impacts students' readiness to continue on to higher education. This situation will also impact the development of the Papua region and even the Indonesian nation itself, thus requiring more intensive attention and support. (Alfasisromarakap et al., 2021).

Seeing the importance of higher education, Lippo Village Christian University (UKLV) as one of the international standard campuses in Indonesia, provides higher education opportunities for every selected and called child from all over Indonesia and even abroad to be able to continue their education with international quality. In ensuring their success in carrying out superior standard education, they must also ensure that prospective students who continue their UKLV education have good self-preparation, especially in terms of numeracy and literacy

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skills which are one of the main foundations in the learning process in higher education. It cannot be denied, if requirements like this are one of the reasons why Papuan children cannot continue their education in higher education. Understanding this problem and need, UKLP provides a Holistic Academic Readiness Preparation Program (HARPP) in collaboration with the Central Papua government as a strategic effort to address this challenge.

The HARPP program is designed to help Papuan children, particularly those in Central Papua, prepare themselves for college through literacy, numeracy, mental, and spiritual skills. The HARPP program prioritizes numeracy, followed by literacy, Indonesian, biblical study, IT, physical health, self-development, citizenship, Pancasila, and includes devotions and chapels. Numeracy is considered crucial for proper preparation, as it serves as a foundation for understanding more complex concepts across various disciplines, including science, technology, economics, and engineering. Numeracy is an essential skill for problem-solving, data analysis, and logical decision-making, a skill highly sought after in today's rapidly changing world. (Nurfadillah et al., 2024) Without adequate numeracy skills, students will struggle to follow lectures, especially in subjects that require a strong mathematical understanding. The HARPP program seeks to address this obstacle by providing innovative method-based learning, such as the Concrete-Pictorial-Abstract (CPA) approach, which is considered effective in improving numeracy understanding. (Hafizhotul Millah et al., 2024) This approach aims to facilitate the understanding of mathematical concepts through systematic and structured stages, starting from direct experience with concrete objects, then continuing with visual representations, and finally involving abstract symbols used in mathematical formulas. (Shafira et al., 2023).

In designing numeracy interventions, the CPA approach was chosen theoretically and contextually. Theoretically, this approach aligns with Bruner's representation theory, which emphasizes that conceptual understanding develops through enactive (direct action/physical objects), iconic (images/visuals), and symbolic (language/abstract symbols) stages. (Syifa et al., 2020). Various international studies have shown that CPA is effective in helping learners build more stable mental representations before moving on to formal mathematical symbols. (Suryaningsih, 2025). Most CPA research is conducted in the context of elementary schools or regular formal education. Few studies have examined the effectiveness of CPA in the context of college preparation, particularly for prospective students from indigenous communities or marginalized areas such as Central Papua. Meanwhile, the CPA approach in HARPP is designed not only as a pedagogical strategy, but as a bridge for cognitive transition by using the context of objects and situations close to the participants' life experiences. Furthermore, the application of CPA in HARPP does not simply follow the pattern of formal school learning, but is adapted to the cultural context of the participants and is directed at preparing for advanced abstract thinking required in college. Based on this research background, this study aims to evaluate the effectiveness of the CPA approach in improving the numeracy skills of prospective Central Papuan students in the HARPP program and identify the developments and challenges experienced by participants during the learning process. Thus, this study is expected to provide a theoretical contribution regarding the relevance of the representational approach in marginalized contexts.

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## Method

This study uses a mixed method approach with a sequential explanatory design, namely a combination of quantitative and qualitative methods carried out sequentially to obtain a comprehensive understanding of the effectiveness of the CPA approach in improving participants' numeracy skills. (Khoiri et al., 2026) In the first stage, quantitative data was collected through diagnostic tests and numeracy evaluation tests administered before and after learning to identify initial abilities and measure the development of participants' numeracy skills. The second stage continued with qualitative data collection through learning observations and semi-structured interviews to gain a deeper understanding of the learning process, thinking strategies, and challenges experienced by participants during learning using the CPA approach (Ningrum et al., 2024). The research subjects were 25 prospective students from Central Papua who were participating in the academic preparation program for higher education. The research instruments included a numeracy test, interview guides, and learning observation sheets. The numeracy test was used in the form of a diagnostic and evaluation test compiled based on the participants' numeracy ability indicators. The interview guide was used to explore the participants' learning experiences and difficulties, while the observation sheets were used to record learning activities, participant engagement, and their responses to the use of teaching aids and visual representations in learning. To ensure the quality of the instrument, the numeracy test was validated by two mathematics education experts and one linguist through content validation to ensure the consistency of the instrument. The research process was carried out in three stages: preparation, implementation, and evaluation. In the preparation stage, the researcher analyzed the need for numeracy materials that were contextual to Papuan culture. The implementation stage involved the gradual implementation of CPA. Evaluation was carried out through diagnostic and evaluation tests to measure numeracy development, as well as observation and interviews to obtain qualitative data. The data is analyzed descriptively and thematically to describe the increase in numeracy skills as well as supporting and inhibiting factors, so that the research results can become a reference for developing more effective education programs in areas with similar challenges. (Munfariqoh et al., 2025).

## Results and Discussion

### Results

The research results are presented based on two types of data collected in accordance with the mixed methods explanatory sequential research design: quantitative data from numeracy tests and qualitative data from learning observations and participant interviews. The presentation of the research results focuses on two main aspects: the development of participants' numeracy skills after participating in learning with the CPA approach and changes in participants' learning experiences during the learning process. Numeracy learning in the HARPP program is preceded by a diagnostic test to assess the basic abilities of prospective students from Central Papua. This opening test consists of simple operations on integers, fractions, and decimals, units of measurement, geometry, algebra, and simple statistics. After conducting the diagnostic test, the results obtained indicate the participants' basic numeracy abilities, as recorded below.

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The results of the diagnostic test administered at the beginning of the program indicated that participants' initial numeracy skills were still at a low level. The average overall score for participants was 3.34, indicating that most participants did not yet have adequate mastery of the basic numeracy concepts needed to support academic readiness in higher education. Further analysis showed that participants experienced difficulties, especially with questions requiring conceptual understanding, such as fraction operations, contextual problem solving, and geometric representations. These findings indicate a gap between previous mathematics learning experiences and the numeracy skills required in higher education.

**Table 1. HARPP Numeracy Diagnostic Test Results**

| Name    | Number and Algebra Operations (1-10) | Measurement (11-20) | Statistics and Decimal Numbers (21-30) | Number and Fraction Operations (31-35) | Geometry (36-40) | Ability (%) |
|---------|--------------------------------------|---------------------|--|--|------------------|-------------|
| AME     | 10                                   | 7                   | 9                                      | 4                                      | 2                | 82.1        |
| APGK    | 2                                    | 1                   | 0                                      | 0                                      | 0                | 0.7         |
| APGK    | 2                                    | 1                   | 0                                      | 0                                      | 0                | 0.7         |
| ADRL    | 6                                    | 4                   | 4                                      | 1                                      | 2                | 43.6        |
| AW      | 5                                    | 6                   | 3                                      | 0                                      | 0                | 35.9        |
| AHK     | 6                                    | 0                   | 4                                      | 0                                      | 0                | 25.6        |
| BRM     | 10                                   | 6                   | 9                                      | 3                                      | 3                | 79.5        |
| BW      | 3                                    | 0                   | 0                                      | 0                                      | 0                | 0.7         |
| BBP     | 6                                    | 4                   | 5                                      | 0                                      | 0                | 38.5        |
| PH      | 9                                    | 4                   | 7                                      | 1                                      | 1                | 56.4        |
| JA      | 5                                    | 3                   | 3                                      | 0                                      | 0                | 28.2        |
| KCGS    | 5                                    | 1                   | 1                                      | 0                                      | 0                | 17.9        |
| LG      | 5                                    | 2                   | 3                                      | 0                                      | 0                | 25.6        |
| LM      | 7                                    | 5                   | 2                                      | 1                                      | 2                | 43.6        |
| PK      | 4                                    | 3                   | 1                                      | 0                                      | 0                | 20.5        |
| RLA     | 4                                    | 2                   | 1                                      | 0                                      | 1                | 20.5        |
| RVR     | 8                                    | 4                   | 6                                      | 2                                      | 3                | 59          |
| SO      | 7                                    | 4                   | 3                                      | 1                                      | 0                | 35.9        |
| VMK     | 5                                    | 1                   | 5                                      | 0                                      | 0                | 28.2        |
| YOH     | 8                                    | 1                   | 4                                      | 0                                      | 0                | 33.3        |
| YR      | 6                                    | 0                   | 1                                      | 0                                      | 0                | 17.9        |
| FW      | 4                                    | 2                   | 4                                      | 0                                      | 0                | 25.6        |
| GW      | 7                                    | 5                   | 3                                      | 0                                      | 1                | 41          |
| RYR     | 2                                    | 0                   | 3                                      | 1                                      | 2                | 20.5        |
| VMP     | 5                                    | 1                   | 0                                      | 0                                      | 0                | 15.4        |
| PM      | 7                                    | 3                   | 9                                      | 0                                      | 2                | 53.8        |
| Average |                                      |                     |  |  |                  | 3.34        |

Based on these results, it can be concluded that there are several key issues that need to be addressed when implementing numeracy learning. First, the students' poor understanding of basic mathematical concepts indicates that they need a more concrete and gradual learning approach to better understand the material. Second, the wide variation in ability among the students indicates that the learning method must be more adaptive and able to accommodate different learning needs. Third, the limited understanding of fractions, statistics, and geometry indicates that the students do not yet have sufficient experience in connecting mathematical concepts to their real lives. This can be a major challenge in higher education, where numeracy plays a role not only in mathematics learning but also in various other disciplines. (Kurniawan et al., 2025).

To address these challenges, a more effective, experiential learning approach is needed. The CPA approach is one solution that can help students understand mathematical concepts more systematically. This approach allows students to begin learning from direct experience using real objects familiar to them, before moving on to visual representations and, finally, to more formal abstraction. (Iyamuremye & Burns, 2025). With this method, participants can develop a stronger understanding because they are not immediately confronted with symbols and numbers, but rather given the opportunity to gradually grasp the concepts. In the context of Papuan children, using objects relevant to their lives can be an effective strategy for building connections between mathematics and their everyday experiences.



(a) (b)

**Figure 1.** Learning process with (a) concrete stage and (b) pictorial stage

The first topic in numeracy learning is number recognition, starting from units, tens, hundreds, thousands, and so on. After ensuring that participants have recognized and understood numbers, they will continue with learning about number operations. The diagnostic results show that participants' understanding of number operations is very low, using both integers, decimals, and fractions. When grouped according to their abilities, the diagnostic results for number operations show that most students are still in the very low category. Approximately 85% of students are in the category of not having a basic knowledge of number operations. Their errors even occur in basic operations ranging from addition, subtraction, multiplication, and division. Approximately 15% of students begin to understand some basic concepts but still experience many errors in solving more complex problems or in the form of

word problems. Considering that number operations are very important material and the participants have very low abilities in this part of the concept, the learning process using the CPA approach will be demonstrated in this learning topic.

**Table 2.** Evaluation results of learning numbers for 25 participants

| Operation Material              | Development process (<30-45) | Starting to Develop (46-60) | Well developed (61-80) | Highly Developed (81-90) | Extraordinary Growth (91-100) | Increase (%) |
|---------------------------------|------------------------------|-----------------------------|------------------------|--------------------------|-------------------------------|--------------|
| Addition and Subtraction        | -                            | -                           | -                      | -                        | 25                            | 95           |
| Multiplication and Distribution | -                            | -                           | -                      | 8                        | 17                            | 90           |
| Numbers in Context              | -                            | -                           | 6                      | 5                        | 14                            | 85           |
| Composite Numbers, Contextual   | -                            | 12                          | 4                      | 6                        | 3                             | 75           |

After the numeracy learning process was conducted using the CPA approach, there was a very significant improvement in participants' ability to complete number operations. Evaluation results showed that approximately 95% of participants experienced improvements in addition and subtraction, while approximately 90% of participants showed significant progress in multiplication and division. Additionally, approximately 75%-85% of participants began to be able to solve problems involving combinations of number operations in everyday contexts. This improvement not only demonstrates that participants have mastered number operations technically but also that they have understood how mathematics can be applied to their daily lives in more relevant ways.

After the learning and evaluation for the number material was deemed sufficient, the learning continued with geometry material while still applying the CPA approach as the main method in the learning process. Judging from the diagnostic results, the participants' initial understanding of geometry was also very low. The overall geometry learning consisted of topics such as length and area, volume and surface area, right triangles and Pythagoras, Cartesian coordinates and lines. Using the same method, the geometry learning process was also carried out with a CPA approach and always ended with an assessment evaluation. To monitor the participants' progress, the researcher chose the topic of Cartesian coordinates and lines as a representative of the participants' development results. The assessment results for the topic of Cartesian coordinates and lines are as follows.

**Table 3.** Results of the evaluation of learning Cartesian coordinates, lines and angles for 25 participants

| Material Geometry   | Development Process (<30-45) | Starting to Grow (46-60) | Developing well (61-80) | Highly Developed (81-90) | Extraordinary Growth (91-100) | Improve ment (%) |
|---|------------------------------|--------------------------|-------------------------|--------------------------|-------------------------------|------------------|
| Coordinate Location                                       | -                            | 2                        | 8                       | 4                        | 11                            | 84.8             |
| Coordinate points and unit distance                       | -                            | 3                        | 8                       | 2                        | 12                            | 82               |
| Drawing coordinates, coordinate points, calculating area, | -                            | -                        | 3                       | 7                        | 15                            | 92.5             |
| Lines and Angles  | 1                            | 5                        | 6                       | 9                        | 4                             | 78               |

After the implementation of CPA-based learning, significant changes occurred. In the coordinate location material, 84.8% of participants experienced rapid improvement. They were not only able to identify points in the coordinate system, but also understood how to determine the relative position of a point to the x- and y-axes. While previously participants had difficulty measuring distances between points in coordinates, they now showed an improvement of up to 82%, with most participants able to accurately calculate distances in Cartesian coordinates. 92.5% of participants showed significant improvement in drawing and analyzing coordinate points, which they had previously been barely able to do. 78% were also able to calculate area in Cartesian coordinates, compared to almost none of the participants previously. The learning process using a concrete approach with physical objects and visual representations such as simple maps or simulation models significantly helped participants understand the learning concepts. (Rahmadani et al., 2022). In this case, the teacher helps participants understand that coordinates are not just numbers on a graph, but rather a navigation system used in everyday life.



**Figure 2.** Learning process with abstract

Observations show that learning using the CPA approach helps participants become more active in the learning process, especially when using concrete objects and visual representations to understand mathematical concepts. The engaging and structured learning, which aligns their experiences with what they will learn, significantly helps boost participants' confidence in learning. (Iyamuremye & Burns, 2025) In interviews, several participants stated that the learning approach used helped them understand mathematical concepts more clearly. One participant stated: "Previously, I was afraid when I saw math problems, especially those with stories. But when I learned using objects and pictures, and explained with easy-to-imagine examples, I could understand how to calculate them." Another participant also said that the use of pictures and models helped them understand the relationships between mathematical concepts. "If I just calculated using numbers, I would be confused, but when I drew them first, I could see how to get the answer." This shows that the CPA approach not only helped improve academic numeracy but also contributed to changes in participants' learning attitudes.

## Discussion

The results of the study indicate that the CPA approach has a significant impact on improving the numeracy skills of prospective students from Central Papua who participated in the HARPP program. This finding is in line with the research objective of evaluating the effectiveness of the CPA approach in helping participants develop a conceptual understanding of mathematics in preparation for entering higher education. Before the implementation of this approach, initial diagnostic results described a fairly worrying condition, where most participants did not have a sufficient understanding of basic numeracy concepts. When viewed from 25 participants, 95% of participants showed very significant progress in addition and subtraction operations, 90% in multiplication and division operations, and 75-85% of participants were also able to manage various types of numbers in one problem solving, with a broader context. In the material on coordinate location, as many as 84.8% of participants experienced rapid improvement by showing an increase of up to 82% in terms of understanding

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the concept of the material, and as many as 92.5% of participants showed significant progress in drawing and analyzing coordinate points, which they were previously almost unable to do. Likewise, 78% of participants became able to calculate the area in Cartesian coordinates, compared to almost no participants previously.

The finding of a very high increase in numeracy skills, particularly in addition and subtraction operations, reaching 95%, can be explained through the cognitive development theory framework proposed by Jerome Bruner. Bruner explained that the process of learning mathematics occurs through three forms of knowledge representation: the enactive stage (direct experience with concrete objects), the iconic stage (visual representation or images), and the symbolic stage (the use of abstract symbols such as numbers and mathematical operations). The CPA approach is essentially a practical implementation of this representation framework in mathematics learning. (Radiusman & Simanjuntak, 2020) When participants first interact with concrete objects, they develop an intuitive understanding of number concepts. This representation is then reinforced through a pictorial stage that allows participants to visually see the relationships between concepts before eventually using mathematical symbols abstractly. (Sutini, 2025). Therefore, the significant increase in ability in this study can be understood as the result of a process of constructing conceptual understanding that occurs gradually in accordance with the stages of cognitive development described by Bruner.

These findings also align with various international studies on the effectiveness of the CPA approach in mathematics learning. Several studies have shown that the systematic use of concrete and visual representations can help students better understand abstract mathematical concepts and improve their mathematical problem-solving skills. (Putri et al., 2025). In the context of this research, the use of real objects and visual models helped participants from Central Papua to connect the concept of numeracy with their daily life experiences. This is very important considering that many participants previously had difficulty understanding mathematics which was presented directly in symbolic form without going through a concrete representation process first.

The success of the CPA approach in improving Papuan children's numeracy understanding in this program is inseparable from its strong pedagogical foundation. This is crucial for providing a gradual learning experience, from concrete to pictorial to abstract. Through the learning process, participants have the opportunity to truly experience, see, and understand mathematical concepts before moving on to symbolic forms. (Azzahrah & Iqbal, 2025). One of the biggest impacts of implementing CPA is changing the way participants understand numbers as meaningful entities, not just mathematical symbols that must be memorized. (Alviansyah, 2025). In the initial stages before the CPA intervention, many participants relied on memorization without truly understanding the relationships between numbers. This difficulty was particularly evident in story-based problems, where participants struggled to translate information into appropriate mathematical operations. After undergoing the CPA process, significant improvements were seen in this area. Participants now more easily recognized the relationships between numbers and numeracy concepts in real-life situations. They were not only able to perform calculations more accurately but also demonstrated improvements in analytical thinking and problem-solving, particularly in the contextual and compound number categories.

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Overall, the CPA approach has been shown to have a very positive impact on improving students' understanding of numeracy, particularly in the context of Papuan children. However, this study has several limitations that require careful consideration. For example, the limited scope of participants was limited to a small group with specific cultural and geographic backgrounds, making the results less likely to be widely generalizable. It should also be noted that the relatively short duration of this approach has prevented a comprehensive evaluation of its impact on long-term retention and application of concepts in more complex real-life contexts. Furthermore, the evaluation's focus on cognitive aspects and quantitative outcomes has left other dimensions such as mathematical communication skills, teamwork, or social-context-based problem-solving understudied. Therefore, further research is needed that explores the application of CPA in more diverse contexts, including educational levels, cultural diversity, and its integration with modern learning approaches.

### **Conclusion**

This study demonstrates that the CPA approach is an effective learning strategy in helping HARPP program participants from Central Papua develop a more conceptual and meaningful understanding of numeracy. Through a learning process that progresses gradually from concrete experiences to visual and symbolic representations, participants can build a more structured understanding of mathematics and are able to connect numeracy concepts to their daily life contexts. These findings reinforce the view in cognitive development theory that effective mathematics learning processes need to pay attention to the stages of knowledge representation in students. Therefore, the CPA approach can be a relevant pedagogical strategy to help students with diverse educational backgrounds prepare for the academic demands of higher education. Practically, this study has implications for the development of numeracy learning policies, particularly in academic preparation programs for students from areas with limited access to education, by emphasizing the importance of contextual, visual, and experiential learning. Therefore, further research is recommended to examine the application of the CPA approach in broader educational contexts, involving a larger number of participants and exploring its integration with other learning strategies to support the development of more complex mathematical skills.

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### **Authors' Note**

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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