

Improving Students' Mathematical Conceptual Understanding of Polyhedra through Formative Assessment

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Abstract. This study aimed to describe the implementation of formative assessment within Classroom Action Research (CAR) and to improve students' mathematical conceptual understanding of polyhedra. The participants were 27 Grade VIII students at MTs Darul Ihsan Nganjuk in the 2025/2026 academic year. The study consisted of a pre-cycle stage, Cycle I, and Cycle II, with each cycle involving planning, action, observation, and reflection. Formative assessment was implemented through oral questioning, student worksheets, practice tasks, classroom discussions, collaborative correction, and feedback. Data were collected through tests, observations, and documentation and analyzed descriptively. The mean score increased from 52.64 in the pre-cycle stage to 74.67 in Cycle I and 91.26 in Cycle II. The findings indicate that formative assessment integrated with feedback, instructional follow-up, and CAR reflection can progressively improve students' mathematical conceptual understanding of polyhedra.

Keywords: formative assessment, classroom action research, mathematical conceptual understanding, polyhedra.

1 INTRODUCTION

Mathematics learning requires students not only to obtain correct answers but also to understand the concepts underlying mathematical procedures. Conceptual understanding enables students to connect ideas, select appropriate procedures, and explain mathematical reasoning when solving problems [1]. In geometry, conceptual understanding is also essential for recognizing meaningful relationships among objects, representations, and geometric properties [2]. In the study of polyhedra, these abilities are required to identify the characteristics of cubes, cuboids, prisms, and pyramids, relate their constituent elements, and correctly determine nets, surface area, and volume.

Conceptual understanding may not develop optimally when instruction emphasizes formula use and final answers. Students may obtain correct results by following memorized procedures without understanding the mathematical reasoning that underlies them. Ota [3] showed that assessment of conceptual understanding can reveal mathematical difficulties that are not always identified through routine instruction. A similar condition was observed in Class VIII A, where the mean pre-action score was 52.64. This finding indicated the need for an instructional intervention capable of identifying students' difficulties and misconceptions while learning was still in progress.

One approach that can support such improvement is formative assessment. Formative assessment should not be understood merely as a test administered during instruction; rather, it is a process of eliciting and using evidence of learning to determine subsequent instructional steps. Black and Wiliam [4] emphasized that assessment is formative when evidence of student achievement is used to make decisions that improve learning. Thus, the formative nature of assessment is determined primarily by how assessment information is used, rather than simply by when the assessment is administered.

In mathematics classrooms, formative assessment enables teachers to identify what students understand, the errors they continue to make, and the support needed to achieve learning goals.

William [5] explained that formative assessment is an integral part of instruction because teaching decisions should be informed by evidence of students' learning progress. Accordingly, oral questions, short exercises, student worksheets, discussions, and tasks can function not only as learning activities but also as sources of evidence about students' thinking processes.

Effective formative assessment requires clear learning goals and success criteria. Heritage [6] described formative assessment as a process that includes establishing learning goals, collecting and interpreting evidence, providing feedback, and determining subsequent instructional steps. In the context of polyhedra, assessment should therefore go beyond evaluating the accuracy of calculations; it should also reveal whether students understand relationships among geometric elements, can explain why particular formulas are used, and can apply concepts in different situations.

Feedback is a central component of formative assessment because information derived from students' responses must be used to help them improve their understanding. Hattie and Timperley [7] explained that effective feedback provides information about the intended goal, the learner's current position, and the next steps needed for improvement. In mathematics learning, feedback may take the form of guiding questions, clarification, collaborative correction, or opportunities to revise solutions, thereby turning errors into useful information for learning.

Formative assessment becomes more effective when teachers use assessment evidence to adjust instruction and provide meaningful feedback. Formative feedback plays an important role in helping students identify gaps in their understanding, improve learning strategies, and enhance academic performance [8].

Formative assessment also creates opportunities for students to participate actively in monitoring and improving their own learning. Andrade and Brookhart [9] conceptualized classroom assessment as part of the regulation and co-regulation of learning when teachers and students use assessment information to guide instruction. In this context, students do not merely receive scores; they also review their thinking, revise responses, compare strategies, and use feedback to construct stronger understanding.

The implementation of assessment for learning in mathematics suggests that assessment becomes more meaningful when it is followed by diagnosis of learning needs, feedback, and instructional follow-up. Yusron and Sudiyatno [10] showed that the effectiveness of assessment for learning is influenced by assessment planning, student involvement, and follow-up actions based on assessment information. This reinforces the view that formative assessment should be positioned as part of the learning process rather than as a separate activity that merely produces scores.

Previous research also demonstrated that Assessment for Learning (AfL) can improve students' mathematics learning outcomes when assessment information is actively used to provide feedback and support learning improvement. Aini et al. reported that cooperative learning combined with AfL produced better mathematics learning achievement compared with conventional learning models, indicating that formative assessment can strengthen students' engagement and understanding during the learning process [11].

Beyond identifying whether an answer is correct or incorrect, formative assessment can reveal the quality of students' mathematical reasoning. Herbert et al. [12] showed that the use of formative assessment rubrics can help identify and develop mathematical reasoning. This finding is relevant to conceptual understanding because teachers need to know not only students' final answers but also how students explain relationships, use representations, and construct justifications when solving problems.

In geometry, the quality of assessment also plays an important role in supporting learning. Ariawan [13] reported that formative assessment methods were associated with geometry learning outcomes, while Bautista [14] showed that error analysis could be used as a formative assessment

activity in geometry instruction. Together, these findings highlight the importance of using students' errors as sources of information for determining clarification and subsequent instructional action.

Students' mathematical conceptual understanding also develops when they are given opportunities to construct, represent, and explain concepts through meaningful learning activities. Parwati et al. [15] reported improved mathematical conceptual understanding through learning supported by visual representations, whereas Nugraha and Prabawanto [16] emphasized didactic activities that encourage students to read, answer, discuss, explain, and construct concepts. These findings support the need for instruction that actively engages students in revising and strengthening their understanding.

Studies directly addressing formative assessment in mathematics learning have also yielded relevant evidence. Rahmadani et al. [17] reported improvements in students' conceptual understanding and problem-solving ability when formative assessment was used continuously in mathematics instruction. Zamzaili et al. [18] likewise demonstrated the relevance of formative assessment to conceptual understanding and stages of geometric thinking. These findings provide an empirical basis for applying formative assessment to the learning of polyhedra.

In this study, formative assessment was used as the classroom action to address students' low mathematical conceptual understanding of polyhedra. The teacher integrated oral questioning, student worksheets, discussion, practice tasks, collaborative correction, and feedback into instruction. Students' responses were used to identify understanding, errors, and misconceptions and then to determine feedback and follow-up actions, allowing students to improve their understanding before instruction proceeded.

The study was conducted with Grade VIII A students at MTs Darul Ihsan Nganjuk during the 2025/2026 academic year. It aimed to describe the implementation of formative assessment through classroom action and the resulting improvement in students' mathematical conceptual understanding of polyhedra. The significance of the study lies in using assessment evidence to provide feedback and instructional follow-up during learning while simultaneously using CAR reflection to improve actions across cycles. Accordingly, the research question was: How can the implementation of formative assessment through classroom action improve Grade VIII students' mathematical conceptual understanding of polyhedra?

2. METHODS

This study employed Classroom Action Research (CAR) in Class VIII A at MTs Darul Ihsan Nganjuk during the 2025/2026 academic year. The participants were 27 Grade VIII students. The study was organized into three stages: a pre-cycle stage, Cycle I, and Cycle II. The pre-cycle stage was used to identify students' initial level of mathematical conceptual understanding. Cycle I and Cycle II each consisted of planning, action, observation, and reflection. Formative assessment served as the classroom action in both cycles.

The classroom action procedure consisted of a pre-cycle stage followed by Cycle I and Cycle II. Each cycle comprised planning, action, observation, and reflection. Formative assessment was embedded in both cycles as the instructional action used to elicit evidence of students' conceptual understanding and to guide feedback and follow-up instruction.

Table 1. Classroom Action Research Procedure

Stage	Main Activities	Evaluation/Observation Focus	Output
Pre-cycle	Conduct an initial observation of the learning process, administer a baseline test of conceptual understanding, and identify students' difficulties and characteristics of understanding related to polyhedra.	Identify students' initial conceptual understanding, patterns of error, and difficulties in understanding polyhedra.	Baseline data and a basis for planning Cycle I.

Stage	Main Activities	Evaluation/Observation Focus	Output
Cycle I – Planning	Prepare instructional materials, student worksheets, formative assessment instruments, oral questions, tasks/exercises, observation sheets, and a feedback mechanism. The formative assessment is designed to reveal students' understanding, errors, and misconceptions.	Determine forms of formative assessment that can generate evidence of students' conceptual understanding and design appropriate feedback and follow-up actions.	Cycle I action plan, including formative assessment, observation, and instructional follow-up tools.
Cycle I – Action	Implement instruction with formative assessment through oral questions, student worksheets, exercises, discussions, or short tasks. Students' responses are analyzed during instruction to identify levels of understanding and difficulties. Based on this evidence, the teacher provides feedback and opportunities for students to improve their understanding.	Elicit evidence of students' understanding during instruction, identify misconceptions or gaps in understanding, and examine students' responses to feedback and follow-up actions.	Information on the development of students' conceptual understanding and documentation of formative assessment and feedback implementation.
Cycle I – Observation	Observe the implementation of instruction and formative assessment, student participation, responses to feedback, and changes in how students understand and explain concepts. At the end of the cycle, administer a conceptual understanding test.	Evaluate implementation of the action and obtain process and outcome data on students' conceptual understanding in Cycle I.	Observation data on the learning process and Cycle I conceptual understanding results.
Cycle I – Reflection	Analyze all Cycle I data, including test results, formative assessment responses, patterns of error, responses to feedback, student participation, and implementation of the action. Use the analysis to identify limitations and improvements for the next cycle.	Evaluate the overall effectiveness of the action and identify aspects of instruction, formative assessment, feedback, or follow-up that require improvement.	Cycle I reflection findings and a revised action plan for Cycle II.
Cycle II – Planning	Redesign the action based on the Cycle I reflection. Improvements may involve formative questions, feedback delivery, use of representations or media, opportunities to revise answers, student grouping, and forms of instructional follow-up.	Ensure that revisions directly address weaknesses identified in Cycle I.	A revised Cycle II action plan based on the Cycle I reflection.
Cycle II – Action	Implement the improved formative assessment. The teacher again elicits evidence of understanding, analyzes responses, provides feedback, and conducts follow-up activities according to students' needs in topics such as nets, surface area, and volume.	Examine the development of students' understanding after the action is revised and evaluate the effectiveness of feedback and follow-up in Cycle II.	Information on the development of students' conceptual understanding and implementation data for the revised action.
Cycle II – Observation	Observe the implementation of the revised action, student participation, responses to formative assessment and feedback, and administer a conceptual understanding test at the end of Cycle II.	Collect process and outcome data to identify changes in students' conceptual understanding following the revised action.	Cycle II observation data and final conceptual understanding results.
Cycle II – Reflection	Analyze and compare data from the pre-cycle stage, Cycle I, and Cycle II and evaluate whether the study's success indicators have been achieved.	Determine the success of formative assessment in improving students' conceptual understanding and whether further action is required.	Conclusion regarding achievement of the action and improvement in students' conceptual understanding.

The pre-cycle stage involved an initial test to identify students' conceptual understanding and difficulties related to polyhedra. The results provided the basis for planning the actions in Cycle I.

Cycle I comprised planning, action, observation, and reflection. During planning, the teacher prepared instructional materials, student worksheets, oral questions, practice tasks, and formative assessment instruments. During the action, formative assessment was used to elicit evidence of students' understanding through oral questions, worksheets, discussions, and exercises. Based on students' responses, the teacher provided feedback and instructional follow-up to improve conceptual understanding. Observation focused on the implementation of the action, student responses, misconceptions, and participation. At the end of the cycle, students completed a

conceptual understanding test. Observation and test results were then reflected upon to determine improvements for Cycle II.

Cycle II followed the same overall procedure, but the action was revised based on the reflection from Cycle I. Improvements included stronger guiding questions, structured practice, collaborative correction, and more focused feedback. At the end of Cycle II, students completed a conceptual understanding test, followed by reflection to evaluate the achievement of the study's success indicators.

Data were collected through tests, observations, and documentation. The test instrument consisted of seven open-ended items developed from indicators of mathematical conceptual understanding.

Data were analyzed descriptively by comparing the development of students' conceptual understanding across the pre-cycle stage, Cycle I, and Cycle II. Observation data and formative assessment evidence were used to explain how the classroom actions were improved from one cycle to the next.

The action was considered successful when the learning process showed improvement from the pre-cycle condition through Cycles I and II and when the quantitative results demonstrated progressive improvement.

3. RESULTS AND DISCUSSION

The findings are presented according to the stages of Classroom Action Research: the pre-cycle stage, Cycle I, and Cycle II. The pre-cycle stage described students' initial conceptual understanding, while Cycles I and II involved planning, action, observation, and reflection, with formative assessment integrated throughout instruction.

Table 2. Development of Students' Mathematical Conceptual Understanding

Stage	N	Mean Score	Change	Interpretation
Pre-cycle	27	52.64	–	Initial conceptual understanding
Cycle I	27	74.67	+22.03 from pre-cycle	Improvement after the Cycle I action
Cycle II	27	91.26	+16.59 from Cycle I; +38.62 from pre-cycle	Further improvement after revision of the action in Cycle II

In the pre-cycle stage, the mean conceptual understanding score of the 27 students was 52.64. This result indicated that students' initial understanding of polyhedra required improvement. The condition is consistent with previous findings showing that students may struggle to build conceptual connections in mathematics and geometry when instruction emphasizes procedures rather than conceptual meaning [1]–[3]. The pre-cycle findings were therefore used as the basis for planning Cycle I.

In Cycle I, instruction focused on the types, elements, and characteristics of cubes, cuboids, prisms, and pyramids. Formative assessment was implemented through oral questions, student worksheets, exercises, and discussion to obtain information about students' understanding and difficulties during learning. Based on students' responses, the teacher provided feedback through guiding questions, clarification, and opportunities to revise answers. This pattern is consistent with formative assessment principles that position evidence of learning as the basis for subsequent instructional decisions [4]–[6].

The end-of-Cycle I test yielded a mean score of 74.67, an increase of 22.03 points from the pre-cycle stage. This improvement indicated development in students' conceptual understanding following the first action. However, observations and student responses showed that some students still had difficulty connecting geometric concepts with problem-solving procedures. This finding

reinforces the importance of assessment that not only identifies final answers but also reveals students' thinking and reasoning processes [3], [12].

The Cycle I findings informed reflection and revision of the action. Reflection was based not only on end-of-cycle scores but also on patterns of error, student engagement, responses during formative assessment, and the effectiveness of feedback. Based on this reflection, Cycle II strengthened guiding questions, structured practice, collaborative correction, opportunities to revise answers, and feedback tailored more closely to students' difficulties. These improvements are consistent with the principle that feedback should direct subsequent learning [7] and support students' regulation of their own learning processes [9].

Cycle II focused on nets, surface area, and volume of polyhedra. Formative assessment was again used to elicit evidence of students' understanding during instruction. When incomplete or incorrect responses were identified, the teacher provided guiding questions, clarification, collaborative correction, and opportunities to revise solutions. This approach is consistent with assessment for learning, which emphasizes diagnosis of student needs, feedback, and instructional follow-up as integrated components of learning [10].

At the end of Cycle II, the mean conceptual understanding score reached 91.26. This represented an increase of 16.59 points from Cycle I and 38.62 points from the pre-cycle stage. The progression from 52.64 in the pre-cycle stage to 74.67 in Cycle I and 91.26 in Cycle II indicates a sustained improvement in conceptual understanding throughout the classroom action process. The result also supports the view that conceptual understanding can develop when students are given opportunities to construct, represent, explain, and actively revise concepts [15], [16].

The findings show that formative assessment functioned not merely as a tool for measuring learning outcomes but as an integral component of instruction. Oral questions, student worksheets, exercises, discussions, and tasks provided information about students' understanding while learning was taking place. The teacher used this information to determine appropriate feedback and follow-up actions. This is consistent with research that conceptualizes formative assessment as an evidence-based process for adapting instruction [4], [5], as well as with the use of formative rubrics to reveal the quality of students' mathematical reasoning [12].

In geometry learning, using errors as sources of information is particularly important because procedural mistakes may be rooted in conceptual misunderstanding. In this study, incomplete or incorrect responses were not treated as final outcomes; instead, they were used to determine clarification and remedial learning activities. This pattern is consistent with research on formative assessment in geometry [13] and with the use of error analysis as a formative activity to support improvement in student learning [14].

The findings also reinforce previous studies that directly link formative assessment with mathematics learning. Rahmadani et al. [17] showed that formative assessment accompanied by instructional improvement can enhance students' conceptual understanding and problem-solving ability. Zamzaili et al. [18] likewise highlighted the relevance of formative assessment to conceptual understanding and stages of geometric thinking. The convergence of these findings suggests that the value of formative assessment lies in using assessment information to respond to students' learning needs rather than merely administering tests at regular intervals.

The improvement observed in Cycle II also illustrates the role of reflection in CAR. The second-cycle action did not simply repeat Cycle I; rather, it was developed in response to weaknesses identified in the previous cycle. At the student level, formative assessment and feedback supported improvement in understanding during instruction; at the classroom-action level, reflection was used

to improve the instructional design for the following cycle. Thus, these two improvement processes are complementary but serve distinct functions.

Overall, implementing formative assessment through two cycles of classroom action was associated with positive development in students' mathematical conceptual understanding. Formative assessment helped the teacher elicit evidence of understanding, provide feedback, and determine immediate follow-up, while CAR reflection enabled the instructional action to be improved from one cycle to the next. Accordingly, the increase in mean scores should be interpreted as part of a gradual process of instructional improvement within the class studied.

4. CONCLUSION

The findings indicate that implementing formative assessment through Classroom Action Research improved Grade VIII students' mathematical conceptual understanding of polyhedra. Formative assessment was embedded in instruction through oral questions, student worksheets, exercises, discussions, and short tasks to obtain information about students' understanding and difficulties. This information was then used to provide feedback and instructional follow-up, enabling students to improve their understanding while learning was still in progress.

Students' conceptual understanding improved progressively, with the mean score increasing from 52.64 in the pre-cycle stage to 74.67 in Cycle I and 91.26 in Cycle II. Thus, the mean increased by 22.03 points from the pre-cycle stage to Cycle I and by 16.59 points from Cycle I to Cycle II, for an overall increase of 38.62 points.

The improvement was also supported by revisions to the classroom action across cycles. Reflection on Cycle I informed changes in Cycle II, including stronger guiding questions, structured practice, collaborative correction, opportunities to revise answers, and feedback that was more responsive to students' difficulties. These findings indicate that formative assessment functions not only as an assessment technique but also as part of the instructional action, while CAR reflection supports improvement in the quality of the action from one cycle to the next.

In conclusion, formative assessment combined with feedback, instructional follow-up, and action improvement through CAR reflection can support the gradual development of students' mathematical conceptual understanding of polyhedra.

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