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Implementation of Problem-Based Learning to Enhance Students' Critical-Thinking Activities in Chemistry Learning: A Classroom Action Research at SMAN 1 Pancung Soal

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Abstract

Critical thinking is a crucial skill in chemistry education as it supports students' abilities to analyze, evaluate, and solve problems logically, and it is commonly fostered through learning activities such as questioning, discussion, and collaborative problem-solving. Preliminary observations revealed that the majority of Grade XI (Phase F) students at SMAN 1 Pancung Soal demonstrated low levels of engagement in discussions, questioning, and the analysis of contextual chemistry problems. This situation highlights the need for a learning model capable of enhancing these critical-thinking-supporting activities. This study aimed to describe the implementation of the Problem-Based Learning (PBL) model and examine the change in students' learning activities that support critical thinking during chemistry instruction. The study employed a Classroom Action Research (CAR) design following the Kemmis and McTaggart model, conducted over three cycles with 36 Grade XI (Phase F) students at SMAN 1 Pancung Soal who were identified through classroom observation and teacher assessment as showing low engagement in these activities. Data were collected using teacher- and student-activity observation sheets validated by expert judges. The results showed a progressive increase in observed learning activities supporting critical thinking, from an average of 39.0% in the pre-cycle stage to 58.0% in Cycle I, 73.6% in Cycle II, and 87.4% in Cycle III (an increase of 48.4 percentage points), placing the students in the highly active category. Improvements were observed across all seven activity indicators, including attention, questioning, expressing opinions, discussion, collaboration, problem-solving enthusiasm, and task punctuality. These findings indicate that PBL implementation was associated with increased learning activities that support critical thinking in chemistry instruction; as this study did not directly measure critical-thinking skills or include a comparison group, whether these activities translate into improved critical-thinking skills should be examined through further research using validated critical-thinking instruments.

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INTRODUCTION

Instruction is a process systematically designed to create a learning environment that enables students to optimally develop their potential, knowledge, skills, and attitudes (Baars et al., 2021). In the context of 21st-century education, instruction no longer focuses solely on the mastery of concepts (content knowledge) but is directed toward mastering various higher-order thinking skills, one of which is critical thinking (Azrai et al., 2020). Critical thinking is a fundamental competency, as students are required to analyze information, evaluate facts, provide arguments based on scientific data, and make rational decisions when facing various real-life challenges (Rihyanti & Budiyanti, 2024).

Critical thinking underpins the process of reflective and rational thought used to determine what to believe or do (Ennis, 2011; Kurniawan et al., 2021). It is not an innate skill that develops automatically; rather, it must be continuously cultivated through learning experiences rich in inquiry, problem-solving, interactive discussion, and critical evaluation (Alsaleh N. J, 2020; Huber & Kuncel, 2016). Consequently, the learning process should be designed using a student-centered approach that encourages active participation in asking questions, constructing arguments, and connecting concepts.

It is important to distinguish between critical thinking as a cognitive skill and the learning activities that support its development. As a cognitive skill, critical thinking is commonly operationalized through processes such as interpretation, analysis, evaluation, inference, explanation, and self-regulation, and is typically measured using validated cognitive tests or rubrics. Behavioral indicators such as attention to explanations, question-asking, willingness to express opinions, participation in discussion, collaboration, enthusiasm for problem-solving, and punctuality in submitting tasks instead reflect learning engagement and participation, which provide the behavioral conditions under which critical thinking can develop but do not by themselves constitute direct measures of critical-thinking skill. Building on this distinction, the present study conceptualizes its outcome variable as learning activities that support the development of critical thinking, rather than critical-thinking skill itself, and frames the implementation of PBL accordingly.

In chemistry education, critical thinking skills play a crucial role because chemical concepts are characterized by their abstract nature and interconnectedness, requiring analytical ability to understand the relationships between these concepts and everyday phenomena. Students are not merely expected to memorize concepts; they must also be able to explain phenomena, analyze information, and apply chemical concepts to solve problems (Leny et al, 2024).

However, in Chemistry instruction, it is still observed that students' critical thinking skills have not developed optimally. Students tend to accept information from the teacher without further analysis, are less active in asking questions, and struggle to connect Chemistry concepts with contextual issues (Tantu, 2018).

Based on preliminary observations of Grade XI (Phase F) Chemistry lessons at SMAN 1 Pancung Soal, it was found that activities fostering students' critical thinking skills remain at a low level. This situation is evident from low student participation in discussions, a lack of confidence in expressing opinions, and limited ability to analyze the chemistry problems presented. A teacher-dominated instructional process results in students primarily receiving information rather than constructing knowledge through inquiry; consequently, opportunities for students to practice critical thinking skills are limited.

These issues highlight the need to implement an instructional model that transforms learning into a more active, student-centered process. One such model capable of enhancing critical thinking skills is Problem-Based Learning (PBL) (Gunawan et al., 2023). PBL is an instructional approach that uses real-world problems as the foundation for learning activities, thereby encouraging students to seek solutions through processes involving inquiry, information analysis, discussion, and evaluation (Langitasari et al, 2021). Through the PBL framework, students are trained to identify problems, organize learning activities, conduct individual and group inquiries, present problem-solving results, and reflect on the problem-solving process. These stages provide a learning experience that fosters the development of critical thinking skills, as students are directly engaged in the process of analyzing and evaluating problems (Miterianifa et al., 2021).

Various studies indicate that implementing the Problem-Based Learning (PBL) model is effective in enhancing students' critical thinking skills in chemistry education. Research by (Tantu, 2018) demonstrates that a classroom action research intervention using a contextual, student-centered teaching approach improved Grade XI students' critical thinking in chemistry, addressing the same pattern of passive, teacher-centered engagement targeted in the present study. This supports the rationale that shifting chemistry instruction toward active, student-centered models such as PBL can address low critical-thinking engagement. Furthermore, research by (Miterianifa et al., 2021) explains that PBL serves as an effective instructional framework for fostering critical thinking skills in chemistry, as problem-solving activities encourage students to analyze, evaluate, and make decisions based on the information they have gathered.

Another study by (Asmi et al, 2024) demonstrates that the development of PBL-based chemistry teaching materials can enhance students' critical thinking skills, as the instruction is designed around contextual problem-solving activities that actively engage students in the learning process. Similarly, research by (Fareza et al., 2024) indicates that implementing the PBL model in chemistry education can improve students' critical thinking skills and chemical literacy through problem-oriented learning activities.

Based on this gap, the study offers novelty in three aspects. First, methodologically, it employs the Problem-Based Learning (PBL) model within a Classroom Action Research (CAR) framework, focusing on the incremental improvement of the learning process through repeated cycles of planning, action implementation, observation, and reflection, in contrast to prior PBL-chemistry studies that predominantly use one-shot experimental or quasi-experimental designs. Second, rather than inferring critical-thinking development solely from a single pre-test/post-test score, this study tracks process-level change by observing seven theoretically grounded learning-activity indicators across successive cycles, providing cycle-by-cycle evidence of how engagement supporting critical thinking develops over time. Third, empirically, no published study has yet examined these activities among Grade XI (Phase F) chemistry students at SMAN 1 Pancung Soal-a school context with student characteristics, resource conditions, and prior instructional patterns distinct from those in previous studies—so this research is expected to provide new contextual evidence regarding the implementation of PBL in chemistry instruction.

Based on the foregoing, this study aims to describe the implementation of the Problem-Based Learning model in Grade XI (Phase F) Chemistry lessons at SMAN 1 Pancung Soal and to analyze the change in students' learning activities that support critical thinking across the implementation cycles. The findings are expected to serve as a reference for teachers, researchers, and policymakers in developing Chemistry instruction that is more innovative, contextual, and oriented toward fostering higher-order thinking skills.

RESEARCH METHODS

This study is a Classroom Action Research (CAR) project utilizing the (Kemmis & McTaggart, R., & Nixon, 2014) model, comprising four key stages per cycle: planning, acting, observing, and reflecting. The research was carried out over three cycles; a cycle was considered complete, and the next cycle initiated, once the reflection stage identified specific obstacles that the following cycle's action plan was designed to address, and the study was stopped after Cycle III because the average activity percentage had reached the "highly active" criterion (>80%) and had stabilized across consecutive observations. The research took place in a Grade XI (Phase F) class at SMAN 1 Pancung Soal during the Educational Field Practice (PLK) period, spanning from July to December of the 2025/2026 academic year. The research subjects were 36 students from the Grade XI (Phase F) class, determined using a total sampling technique because the class constituted a single intact group under the researcher's PLK placement. Prior to the action, the class teacher and the researcher jointly identified this group as exhibiting low engagement in critical-thinking-supporting activities, based on two converging sources: (1) the class teacher's routine daily observation notes and grade-book records from the preceding semester, and (2) a pre-cycle baseline observation conducted by the researcher using the same seven-indicator activity observation sheet described below, which produced an average activity score of 39.0%—within the "less active" category-confirming the teacher's initial assessment and establishing the pre-cycle baseline reported in Table 1.

The research instruments employed included an observation sheet for the teacher's implementation of the PBL model (syntax-fidelity sheet) and an observation sheet for student learning activities supporting critical thinking, supplemented by documentation (photographs and field notes) and the assessment of problem-solving outcomes using a project rubric. The seven indicators used in the student-activity observation sheet were derived by operationalizing behavioral markers commonly associated with engagement in critical-thinking-oriented learning (Alsaleh N. J, 2020; Ennis, 2011) into classroom-observable actions aligned with the PBL syntax: (1) attention to the teacher's explanation, reflecting readiness to interpret the problem presented at the problem-orientation stage; (2) active questioning and (3) willingness to express opinions, reflecting an evaluative disposition toward information encountered during inquiry; (4) participation in group discussions and (5) ability to collaborate, reflecting the analytical exchange of evidence and justification during group investigation; (6) enthusiasm for problem-solving, reflecting inference toward a solution; and (7) punctuality in assignment submission, reflecting self-regulation in completing the problem-solving task. Each indicator was scored on a 1–4 rating scale with behaviorally anchored descriptors for each score level. Both observation sheets underwent content validation by three expert judges (two chemistry education lecturers and one senior chemistry teacher), who rated the relevance of each indicator to the underlying construct; items retained had a content validity ratio consistent with Lawshe's minimum value for a three-judge panel, and validator feedback was used to refine indicator wording and scoring descriptors prior to use. Because each classroom session was scored by two observers (the researcher and a collaborating teacher) working independently before scores were reconciled, inter-rater agreement was checked for each cycle and observation results were retained only when the two observers' ratings were consistent; agreement was reached through discussion for the small number of indicator scores that initially diverged.
Quantitative data analysis techniques were employed to measure the percentage of critical thinking activity achievement using the following equation:

$$\text{Activity Percentage} = \frac{\text{Score Obtained}}{\text{Maximum Score}} \times 100\% \qquad (1)$$

The percentage of critical thinking activity was calculated by comparing the obtained score with the maximum score and multiplying the result by 100%. Subsequently, the percentage was classified into four categories: highly active (81–100%), active (61–80%), moderately active (41–60%), and less active (≤40%). Meanwhile, qualitative data were analyzed through data reduction, data presentation, and conclusion drawing to examine the dynamics of changes in students' academic behavior.

Each cycle followed the planning–acting–observing–reflecting sequence and comprised three 2 x 45-minute meetings, using contextual reaction-rate problems (Cycle I), acid–base problems (Cycle II), and buffer-solution problems (Cycle III) as the PBL trigger cases, all drawn from everyday phenomena familiar to students. At the planning stage of each cycle, the researcher and the collaborating teacher prepared the lesson plan, PBL-based student worksheets, the contextual problem for that cycle, and the observation instruments; at the acting stage, the teacher implemented the five PBL syntax steps (orienting students to the problem, organizing students for learning, guiding individual and group investigation, developing and presenting results, and analyzing and evaluating the problem-solving process) while the observers rated the seven activity indicators; at the observing stage, both observers recorded scores together with field notes and photographic documentation; and at the reflecting stage, the researcher and teacher jointly reviewed the observation results to identify obstacles and plan refinements for the next cycle. The success criterion for the action was an average activity percentage in the "highly active" category (>80%) sustained across indicators, which was reached in Cycle III. Specific refinements introduced between cycles are reported together with the corresponding results in the following section.

RESULTS AND DISCUSSION

The implementation of the Problem-Based Learning (PBL) model in Grade XI (Phase F) Chemistry lessons at SMAN 1 Pancung Soal demonstrated an increase in student learning activity, fostering the gradual development of critical thinking skills across each research cycle. This improvement was evident in the shift in students' learning behavior; they became increasingly active in identifying problems, seeking relevant information, engaging in group discussions, sharing ideas, and evaluating potential solutions. The study's findings indicate that implementing PBL not only influences cognitive learning outcomes but also enhances the learning process by actively involving students in knowledge construction.

Problem-Based Learning (PBL) is an instructional model grounded in constructivism—an approach viewing knowledge not as something passively acquired through the transmission of information, but as something constructed by students through meaningful learning experiences. In PBL, authentic problems serve as a stimulus for students to conduct inquiries, connect concepts to real-world phenomena, and develop solutions based on their analysis. According to Howard S. Barrows, the defining characteristic of PBL is the use of complex problems as a starting point for learning, encouraging students to engage in active thinking processes rather than merely receiving information from the teacher. Consequently, PBL is highly suitable for chemistry instruction, as chemical concepts often relate to phenomena that require analytical and problem-solving skills.

The development of learning activities supporting students' critical thinking skills was observed through seven activity indicators during the learning process: attention to the teacher's explanation, active questioning, willingness to express opinions, participation in group discussions, ability to work collaboratively in a team, enthusiasm for problem-solving, and punctuality in completing assignments. Data regarding the improvement in student activity—from the initial state (pre-cycle) through to Cycle III-are presented in Table 1.

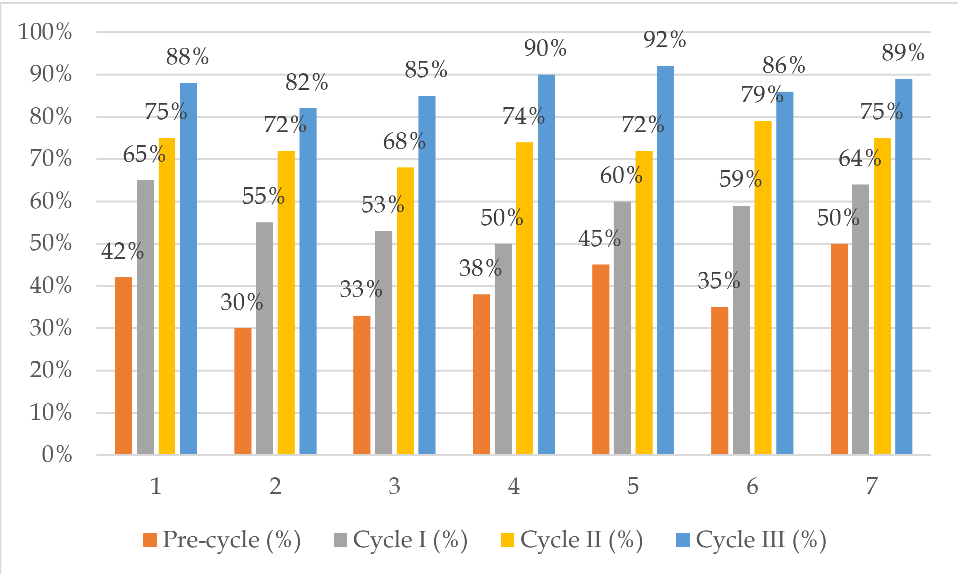
Table 1. Percentage of Students' Critical Thinking Activities per Cycle

Indicators of Critical Thinking Activity	Clasroom Action Research Cycle (%)				Final Criteria
	Pre-cycle	Cycle I	Cycle II	Cycle III	
Pay attention to the teacher's explanation	42	65	75	88	Highly Active
Activeness in asking questions	30	55	72	82	Highly Active
Courage to express opinions	33	53	68	85	Highly Active
Participation in group discussions	38	50	74	90	Highly Active
Teamwork skills	45	60	72	92	Highly Active
Enthusiasm for solving problems	35	59	79	86	Highly Active
Punctuality in tasks	50	64	75	89	Highly Active
Average	39,0	58,0	73,6	87,4	Highly Active

Based on Table 1, it is evident that all activity indicators consistently improved across each learning cycle. Average student activity rose from 39.0% in the pre-cycle stage to 58.0% in Cycle I, increased further to 73.6% in Cycle II, and reached 87.4% in Cycle III, placing it in the "very active" category. This increase of 48.4 percentage points from the initial state was associated with the implementation of the PBL model, coinciding with a shift in observed student learning patterns—from an approach primarily focused on teacher-led information delivery toward one in which students actively constructed understanding through a process of inquiry. As this study used a single-group CAR design without a comparison class, this association cannot be interpreted as definitive causal evidence that PBL alone produced the change.

During the pre-cycle stage, low levels of student activity indicated that the learning process did not yet fully provide opportunities for students to develop higher-order thinking skills. Students tended to passively accept concepts presented by the teacher rather than engaging in questioning, formulating arguments, or analyzing chemistry problems. Consequently, opportunities for students to practice or demonstrate critical-thinking processes appeared limited. This aligns with the views of (Ennis, 2011), who described critical thinking as a complex ability involving interpretation, analysis, evaluation, inference, and reasoning—processes that do not emerge automatically but must be cultivated through planned learning experiences.

To illustrate the progression of the average level of students' critical thinking activities across each cycle, the increase is presented graphically in Figure 1.



Picture 1. Progression of Students' Observed Critical-Thinking-Supporting Activities

Following the implementation of the PBL model in Cycle I, student activity increased, reaching an average of 58.0%. This increase indicates that using problems as a learning stimulus began to influence student engagement; students started participating in discussions, seeking information, and sharing their ideas. However, reflection on Cycle I revealed several remaining challenges: some students were not yet accustomed to identifying problems independently and still relied on teacher guidance, while not all group members participated actively in the inquiry activities.

This situation indicates that shifting from teacher-centered to student-centered learning requires a process of adaptation. Students accustomed to receiving information directly need to be provided with gradual learning experiences to develop independent thinking skills. According to (Tawfik et al., 2021), the successful implementation of PBL depends not only on the presentation of the problem but also on the teacher's ability to provide scaffolding—a form of instructional support that helps students understand the problem, devise solution strategies, and construct knowledge independently.

Improvements to instruction in cycles II and III were implemented by presenting more contextual problems, clarifying the allocation of group tasks, providing guidance during the investigation process, and strengthening discussion activities. These strategies positively impacted student engagement. This was evidenced by the rise in average activity levels to 73.6% in cycle II and 87.4% in cycle III. Such improvement demonstrates that the more effectively the PBL framework is implemented, the greater the opportunities for students to engage in higher-order thinking processes. These findings align with research by (Fajriani et al., 2021), which indicates that providing scaffolding in problem-based learning helps students understand problems, develop solution strategies, and enhance higher-order thinking skills.

The stages within the PBL syntax are directly linked to the development of students' critical thinking indicators. During the problem orientation stage, students are presented with a chemistry problem related to real-world phenomena, thereby stimulating curiosity and a need to seek information. This activity fosters interpretation skills, as students must comprehend the problem's context and identify the essential information required for the problem-solving process. (Aziza et al., 2025) explains that authentic problems in PBL serve as learning triggers, encouraging students to explore and construct understanding based on experience.

During the stage of organizing students for learning and inquiry, students work in groups to gather information, analyze data, and formulate alternative solutions to the problem. These activities contribute to the development of analytical and evaluative skills, as students must compare various pieces of information, consider the evidence obtained, and provide justifications for their chosen solutions. This process demonstrates that Problem-Based Learning (PBL) provides a learning experience aligned with the characteristics of critical thinking skills. This is supported by research by (Wahyudiati, 2022), which demonstrates that the implementation of PBL in chemistry instruction fosters students' critical thinking skills through problem-solving activities, discussions, and independent information processing.

Based on student activity indicators, the largest change was observed in the teamwork indicator, rising from 45% in the pre-cycle stage to 92% by Cycle III. This substantial increase is consistent with, though not sufficient on its own to demonstrate, an effect of Problem-Based Learning (PBL) on students' collaborative engagement; because teamwork is a behavioral-engagement indicator rather than a direct cognitive measure, this rise should not be read as automatic evidence of improved critical-thinking skill. Group inquiry activities provide students with opportunities to exchange ideas, respond to peers' opinions, and develop solutions through a process of group negotiation. Research by (Supriana et al., 2023) indicates that problem-based learning fosters collaboration skills by assigning students shared responsibility for solving a problem.

In addition to collaboration skills, student engagement in group discussions also showed a significant increase, rising from 38% to 90%. This improvement indicates that students were gaining the confidence to participate actively in the learning process. Group discussions within PBL serve not merely as an activity for exchanging information but also as a means for students to develop scientific communication skills, construct arguments, and evaluate opinions based on evidence.

The indicator for active questioning also showed an increase, rising from 30% to 82%. Initially, students tended to passively receive information without seeking clarification on concepts they did not fully grasp. Following the implementation of Problem-Based Learning (PBL), students began actively asking questions, as the assigned problems created a need to seek more in-depth information.

The act of questioning is a crucial component of critical thinking, as it demonstrates an evaluative process regarding the information acquired.

These findings align with previous research indicating that the Problem-Based Learning (PBL) model is effective in enhancing students' learning engagement and critical thinking skills. (Eismawati et al., 2019) stated that PBL fosters critical thinking abilities through problem-solving activities that entail analysis and evaluation. Furthermore, (Mariana et al., 2025) demonstrated that PBL can boost student learning engagement through discussion, inquiry, and group collaboration.

Research by (Putri et al., 2025) also found that PBL enhances students' scientific communication skills through activities such as asking questions, expressing opinions, and presenting arguments. This is supported by (Stevana et al., 2025), who state that problem-based learning can improve collaboration and critical thinking skills because students are directly involved in the process of finding solutions. Furthermore, (Pradani et al., 2023) and (Supriana et al., 2023) demonstrate that PBL contributes to the enhancement of critical thinking skills, learning independence, and problem-solving abilities.

Based on the overall research findings, the increase in learning activities that support critical thinking is influenced not only by the choice of learning model but also by the quality of the PBL syntax implementation, the relevance of the problems presented, and the teacher's ability to provide guidance during the learning process. The uneven gains across indicators—largest for teamwork (45% to 92%) and group discussion (38% to 90%), smaller for questioning (30% to 82%)—are consistent with the reflection notes from each cycle: task and role restructuring introduced after Cycle I directly targeted collaboration and discussion, whereas questioning behavior depended more on individual confidence and appeared to shift only gradually as students grew accustomed to a student-centered format. Because this was a single-group CAR design without a comparison class or standardized test of critical thinking, factors beyond PBL itself—such as students' increasing familiarity with the observation process, normal maturation over the July–December period, and the researcher's presence as an additional source of attention and feedback—cannot be ruled out as partial contributors to the observed increase. Thus, the implementation of the Problem-Based Learning model in Grade XI (Phase F) Chemistry lessons at SMAN 1 Pancung Soal was associated with a progressive increase in student engagement through activities such as identifying problems, conducting investigations, engaging in discussions, evaluating information, and formulating solutions—both independently and collaboratively—while confirmation that this engagement translates into improved critical-thinking skill would require a subsequent study using a validated critical-thinking test and a comparison group.

CONCLUSION

The implementation of the Problem-Based Learning (PBL) model in Chemistry lessons for Grade XI (Phase F) at SMAN 1 Pancung Soal was carried out in accordance with the instructional syntax and was associated with a progressive increase in observed learning activities that support the development of students' critical thinking. This improvement is evident in the average percentage of students' critical-thinking-supporting activities, which rose progressively from 39.0% in the pre-cycle stage to 87.4% in Cycle III, placing the students in the "highly active" category. The application of PBL provided students with opportunities to engage actively in identifying problems, discussing, asking questions, expressing opinions, collaborating, and discovering solutions to chemistry-related issues, and these gains occurred progressively over the course of the CAR implementation. Because the study relied on observation of learning activities within a single class, without a comparison group or a validated critical-thinking test, these findings should not be generalized as causal proof of PBL's effectiveness in improving critical-thinking skills across other students or chemistry learning contexts; rather, they indicate that PBL implementation was associated with increased engagement in activities that support critical-thinking development. Pedagogically, the findings suggest that structured scaffolding, clear division of roles within groups, and the use of contextual problems are important levers for sustaining this kind of engagement. The findings suggest that PBL may be a viable instructional approach for supporting student engagement in chemistry learning, and future research is recommended to confirm this relationship using validated critical-thinking instruments within a quasi-experimental or comparison-group design.

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