



Development of Active Deep Experience-based Teaching Materials in Collaborative Mathematics Learning

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Abstract

Recent calls for mathematics instruction have emphasized the need for coherent materials that promote active engagement, deep conceptual understanding, and collaborative problem solving. However, many classroom resources still lack integration and comprehensive assessment. In response to this gap, we focused on the foundational topics of greatest common factor and least common multiple as a testbed for a more integrated design. This study aimed to develop and evaluate an Active Deep Experience (ADE) based mathematics teaching material for these topics in a collaborative setting. We used a 4D R&D model (Define, Design, Develop, Disseminate) to align tasks with higher-order thinking skills, establish roles and accountability for group work, and incorporate diagnostic, formative, and summative assessment with rubrics. To ensure content validity, we had five experts review the material using CVI, which resulted in high overall validity with targeted revisions for assessment and accessibility. We also gathered feedback from 15 learners through a 20-item Likert questionnaire, which showed practical to very practical ratings across usability, clarity, time efficiency, collaboration, feedback, and satisfaction. To test effectiveness we conducted a pretest-post test design with 29 students, which yielded a large improvement and high normalized gain. Based on these results, we conclude that the ADE material is valid, practical, and effective, and the packaged resources support classroom adoption and adaptation.

Keywords: active deep experience; collaborative learning; teaching materials

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INTRODUCTION

Recent educational reforms have highlighted the importance of fostering higher-order thinking skills, collaboration, and learner autonomy (Khadka et al., 2025; Kwangmuang et al., 2021; Hamzah et al., 2024). In Indonesia, the Kurikulum Merdeka aims to shift towards student-centered instruction (Fauzan et al., 2023), improve literacy and numeracy (Fatimah & Utami, 2025; Pasaribu, 2023), and empower teacher through more flexible and contextual instructional design (Hamdi et al., 2022; Tunas & Pangkey, 2024). However, policy reports have identified ongoing challenges in implementing these reforms at the school level, including the need for instructional materials that align with higher-order thinking (HOTS) goals and assessment practices that support them (OECD, 2023).

Recent research has consistently shown that active learning has a positive impact on academic achievement and can help reduce performance gaps, particularly in the field of science, technology, engineering, and mathematics (Theobald et al., 2020; Ting et al., 2023). In fact, studies have found that classes with high levels of active engagement tend to have higher exam scores and lower failure rates than traditional lecture-based courses (Martella et al., 2024). Moreover, active-learning interventions have been shown to narrow achievement disparities, including gender gaps in mathematics (Clark, 2023; Di Tommaso

et al., 2024). These findings provide a strong rationale for incorporating student-centered approaches into mathematics teaching materials in a systematic manner.

On the other hand, deep learning requires a high level of cognitive engagement, including analysis and synthesis (Li et al., 2021), making conceptual connections (Xiaoxiao & Dongdai, 2020), and going beyond procedural memorization to create meaning. Several studies have shown that students who engage in deep learning at a high level tend to outperform those who rely on surface approaches (Parmar et al., 2024). Other research has emphasized the important of assessment systems that promote reasoning and reflection rather than simply reproducing answer (Min et al., 2020; Shin et al., 2022). Therefore, teaching materials designed to encourage active, deep learning should include incorporate meaningful tasks, formative feedback, and structured opportunities for reflection.

Recent studies indicate that active and collaborative approaches, alongside assessments emphasizing higher-order thinking skills, are associated with gains in students' understanding and participation (Guajardo et al., 2025; Ng et al., 2022; Qureshi et al., 2023). However, much of this work still focuses on classroom strategies or partial modules and has yet to deliver fully integrated instructional packages that combine active learning with deep conceptual development, clearly structured collaboration, and curriculum-aligned assessment tools that teachers can readily adopt (Abildinova et al., 2025; Børte & Lillejord, 2024; Dewra, 2025). In Indonesia, recent analyses of curriculum–assessment alignment likewise reveal a persistent gap between HOTS expectations and classroom practice (Purwanti et al., 2024), underscoring teachers' need for operational, contextual, and adaptable materials. The novelty of this study lies in developing ADE based materials that explicitly organized the sequence of experience, reflection, conceptualization, and application, while detailing roles and individual accountability within group work. In line with standard introductory recommendations, the study aims to design and develop ADE materials for collaborative mathematics learning and to evaluate their content validity, practicality, and effectiveness.

METHODS

This study employed the 4D (Define, Design, Develop, Disseminate) model by (Thiagarajan et al., 1974) to develop the Active Deep Experience (ADE)-based teaching materials. The 4D model provides a systematic framework for defining needs, designing prototypes, validating products, and disseminating final materials. It has been widely adopted and further refined in instructional design and educational development research (Costa et al., 2022; Reigeluth et al., 2024; Utaminingsih et al., 2024). The model was selected for its structured process that ensures coherence between learning objectives, design specifications, expert validation, and classroom implementation, thus maintaining both scientific rigor and practical feasibility. To summarize the procedural flow, Figure 1 presents the ADE-based material development framework using the 4D model.

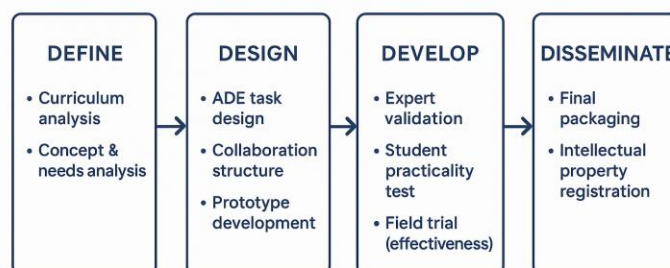


Figure 1. Framework of ADE-based Teaching Material Development using the 4D Model

Figure 1 illustrates the systematic stages of the ADE-based material development process through the 4D model. The following section provides a detailed explanation of each stage within the 4D development process.

1. Define

This stage aims to ensure that needs and development directions align with the intended learning outcomes and learner characteristics so that active and deep learning can occur. The steps were as follows: (1) curriculum analysis of learning objectives for Greatest Common Factor (GCF) and Least Common Multiple (LCM), followed by mapping of HOTS indicators; (2) conceptual analysis and identification of common misconceptions related to GCF and LCM; and (3) needs analysis of students and teachers, including barriers to implementing collaborative learning.

2. Design

This stage aims to design Active Deep Experience through collaborative problem-solving tasks, interaction flows, and assessments that promote conceptual deepening. The steps undertaken were: (1) designing the instructional sequence; (2) establishing the structure of collaboration; and (3) developing prototypes of the teaching materials, reflection sheets, collaborative scenarios, rubrics, and an item bank.

3. Develop

This stage aims to validate the quality of content and design, refine practicality, and examine effectiveness on learning outcomes. The steps undertaken were: (1) content validation by subject-matter experts; (2) practicality testing of the materials through a student response survey; and (3) a field trial conducted over three class meetings through classroom implementation.

4. Disseminate

This stage aims to document and disseminate the teaching materials so they can be replicated or adapted. The steps undertaken were: (1) finalizing the instructional package; and (2) dissemination through intellectual property registration.

Research Subjects

The study was conducted at a public elementary school in West Bandung Regency. Participants comprised a panel of five experts for content validation, 15 students for the practicality study (student responses), and 29 students for the effectiveness trial over three instructional sessions. During the needs-definition stage, two teachers and eight students were additionally involved through brief interviews and initial classroom observations.

Instruments and Data Collection Techniques

The research employed: (a) an expert validation sheet to assess content alignment, disciplinary accuracy, ADE pedagogy, language, presentation, and assessment; (b) a 4-point student practicality questionnaire capturing perceptions of ease of use, clarity, time efficiency, engagement, collaboration, assessment, and satisfaction/intent to use; (c) a learning achievement test containing HOTS-oriented items to measure learning outcomes; (d) an observation sheet for implementation fidelity and collaborative dynamics; and (e) brief interviews with teachers and students to clarify unresolved issues. Data were collected through expert ratings, questionnaire administration, testing (pretest and posttest), classroom observations, and short structured interviews.

Data Analysis Techniques.

The study employed: (1) Content validity analysis by computing the Item-Content Validity Index (I-CVI) for each item (proportion of experts assigning ratings 3-4) and the Scale-Content Validity Index (S-CVI/Ave and S-CVI/UA), with I-CVI \geq 0.80 set as the

acceptance criterion for items and S-CVI used to inform accept/revise decisions at the instrument level. (2) Practicality analysis by converting student responses to the Percentage of Maximum Score (PSM) per student and averaging by dimension, after reverse-scoring negatively worded items. (3) Effectiveness analysis using descriptive statistics for pretest–posttest outcomes, normalized gain with category interpretation, and paired t-test. Qualitative data from expert comments, students’ open responses, and observation notes were analyzed thematically to interpret and enrich quantitative findings and to inform product refinement. All procedures adhered to educational research ethics, including school permission, respondent anonymity, and reporting practices that do not disrupt instructional schedules.

RESULTS & DISCUSSION

Results

Results are presented sequentially following the 4D model, so that their alignment with the research objectives is explicit and easy to trace.

Define

As an initial step in the Define phase, the researchers reviewed the Kurikulum Merdeka learning objectives for Grade 5 elementary mathematics on LCM and GCF, then mapped these competency demands to HOTS indicators to ensure that the collaborative tasks genuinely stimulate active and deep learning experiences. The results of this review and mapping are presented in Table 1.

Table 1. Derived Learning Objectives, HOTS Indicators, and Collaborative Tasks

Derived Learning Objective	HOTS Indicators	Collaborative/ Active-Deep Tasks
Identify factors and multiples of a number; distinguish prime vs. composite numbers.	- Decompose numbers into factors/ multiples and classify them.	In groups, sort numbers into factors/ multiples /prime–composite categories and justify the classifications.
Present prime factorization using exponent notation and multiple representations.	- Construct correct factor trees. - Select the most efficient representation.	Each group creates 2–3 representations for different numbers and compares their efficiency.
Determine GCF and LCM of two or more numbers using multiple strategies.	- Choose the most appropriate GCF/ LCM strategy for given pairs and justify the choice.	Two subgroups solve GCF & LCM with different strategies, then debate the reasons for their selections.
Model contextual problems.	- Identify problem keywords. - Select GCF or LCM appropriately. - Produce a model/ number-line diagram.	Groups map 6–8 word problems to GCF /LCM, model them on a number line/diagram, and present their reasoning.

Table 1 presents the derived learning objectives for Greatest Common Factor (GCF) and Least Common Multiple (LCM), aligned with higher-order thinking skills (HOTS) indicators and corresponding collaborative or active-deep learning tasks. This table serves to illustrate how the curriculum analysis was translated into task designs that promote analytical reasoning, justification, and peer interaction within the ADE framework.

In the next step, the researchers compiled a concept map and an inventory of common misconceptions on GCF and LCM for Grade 5, drawing on a review of learning objectives, textbooks, literature on students' learning difficulties in GCF–LCM, and brief teacher interviews. A synthesis of these findings is summarized in the following table.

Table 2. Core Concepts, Essential Understandings, and Common Student Misconceptions

Core Concept	Essential Understanding	Common Student Misconceptions
Prime vs. composite numbers	<ul style="list-style-type: none"> - 1 is neither prime nor composite. - divides with no remainder; - A multiple is a product obtained by multiplying a number by an integer. 	<ul style="list-style-type: none"> - Believing 1 is prime. - Swapping terms (e.g., saying “12 is a factor of 3”); - Stating a factor larger than the number.
Factors vs. Multiples		
Prime factorization	<ul style="list-style-type: none"> - Writing a number as a product of primes with exponent notation. 	<ul style="list-style-type: none"> - Ignoring repeated primes (e.g., writing $36 = 2 \times 3$ instead of $2^2 \times 3^2$).
GCF (concept & strategy)	<ul style="list-style-type: none"> - GCF = greatest common factor among two or more numbers. 	<ul style="list-style-type: none"> - Taking the largest exponents for GCF.
LCM (concept & strategy)	<ul style="list-style-type: none"> - LCM = the least common multiple shared by two or more numbers. 	<ul style="list-style-type: none"> - Taking the smallest exponents for LCM.
Choosing GCF vs. LCM	<ul style="list-style-type: none"> - Use GCF for maximum equal sharing/partitioning. - Use LCM to synchronize repeating events (“meet again”). 	<ul style="list-style-type: none"> - Solving “meet again” problems with GCF, or “equal sharing” with LCM.

Subsequently, a needs analysis was conducted for both teachers and students, alongside an examination of barriers to collaborative learning as part of the Define phase. The findings of this analysis are presented in the following table.

Table 3. Needs Analysis and Collaborative-Learning Barriers

Category	Key Findings
Students' Needs	a) Concrete explanation of the difference between factors and multiples; b) Step-by-step prime factorization and exponent notation; c) Contextual examples for choosing GCF vs. LCM; d) Opportunities to speak, argue, and rebut reasons.

Category	Key Findings
Teachers' Needs	a) Examples of well-structured collaborative tasks; b) Variation of strategies for GCF–LCM; c) Quick formative assessment and actionable feedback; d) Simple visuals/manipulatives.
Barriers to Collaborative Learning	a) 1–2 students dominate, others passive; b) Method misselection in word problems; c) Limited practice in justifying solutions; d) Prolonged discussions leading to missed final steps.

Design

This section presents the design of the ADE teaching materials for GCF and LCM through a structured scenario. The design is organized into four phases: a contextual hook, active exploration, collaborative problem solving, and deep reflection. In the initial contextual hook, we created two simple, familiar situations that are easy for students to visualize “together again” to foreground LCM and “equal sharing” to foreground GCF. Each problem is accompanied by prompting questions, such as “when will they occur together again?” and “how many per skewer?”, to foster curiosity, activate prior knowledge, and guide students toward the targeted concepts.

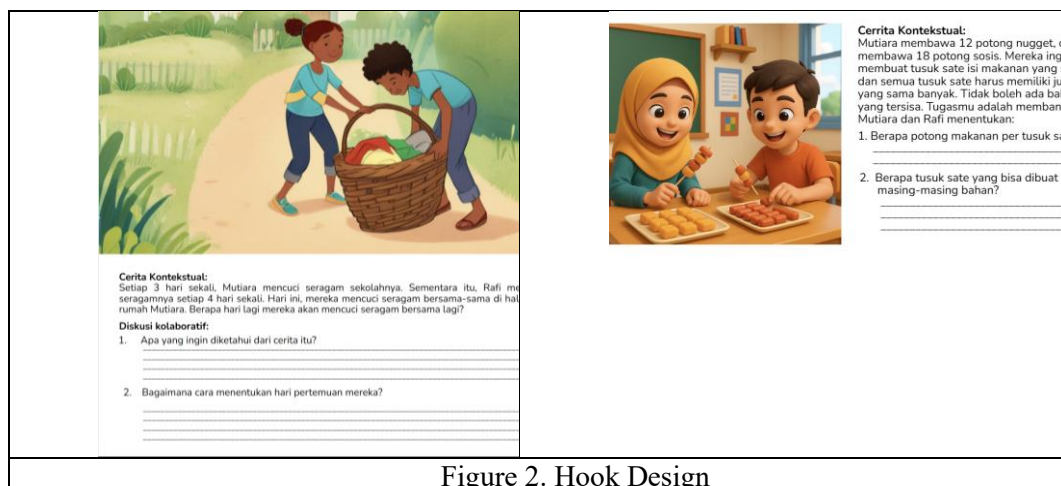


Figure 2. Hook Design

In the active exploration phase, we designed a sequence of tasks that gradually build conceptual understanding distinguishing factors from multiples, identifying primes versus composites, and constructing factor trees that culminate in exponent notation (e.g., $24 = 2^3 \times 3$). To reduce common misconceptions (e.g., “1” is neither prime nor composite; confusion between factors and multiples; errors in exponents), the materials provide step-by-step scaffolding, a factor-tree template, prime-number cards, and a “Mind the Mix-ups!” warning box. We also prepared 3–5 checkpoint items to monitor accuracy in notation and exponents from the outset.

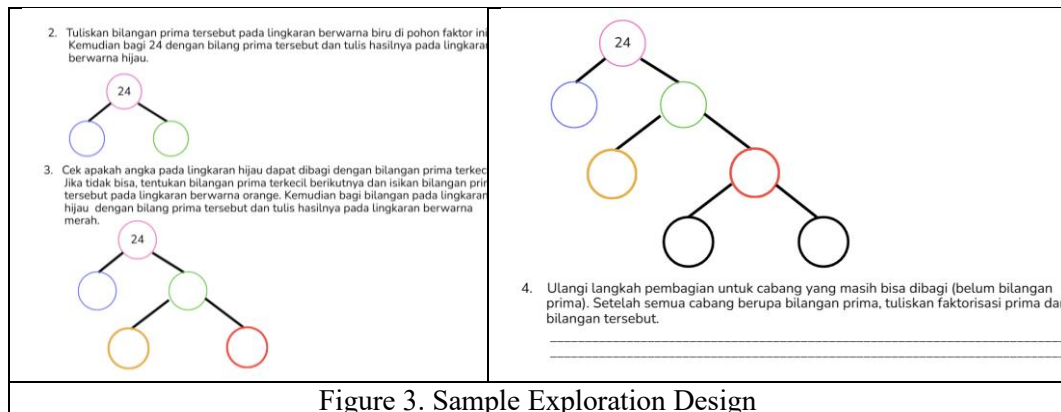


Figure 3. Sample Exploration Design

For the collaborative problem-solving phase, we designed role-based scenarios and a multi-strategy item set in which each task requires students to select a strategy, justify their reasoning, and compare efficiency across analogous cases. To support productive interaction and accountability, the ADE materials include a reasoning and collaboration rubric as well as role sheets that clarify responsibilities and expected contributions for each group member.



<p>Aktivitas Kolaboratif dan Pembagian Peran</p>  <ol style="list-style-type: none"> 1. Siapa yang akan bertugas menjadi Pencatat? _____ (Pencatat bertugas menulis daftar faktor dari masing-masing bilangan) 2. Siapa yang akan bertugas menjadi Penggambar? _____ (Penggambar bertugas menggambar diagram atau tabel faktor) 3. Siapa yang akan bertugas menjadi Penyelesai? _____ (Penyelesai bertugas menentukan FPB dan menjawab pertanyaan cerita.) 4. Siapa yang akan bertugas menjadi Penyaji? _____ (Penyaji bertugas menjelaskan hasil kepada kelompok lain.) 	 <p>Ayo Refleksikan Temuanmu!</p> <ol style="list-style-type: none"> 1. Tuliskan hasil temuanmu. _____ _____ 2. Mengapa FPB mengambil pangkat terkecil sedangkan KPK terbesar? _____ _____ 3. Kapan daftar kelipatan lebih efisien daripada Venn prima? _____ _____ 4. Di sekolah, senam berlangsung setiap 6 hari dan Pramuka setiap 8 hari. Keduanya mulai pada hari yang sama. Kapan keduanya berlangsung bersama lagi? Jelaskan apakah kamu menggunakan FPB atau KPK dan mengapa. _____ _____
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Figure 4. Sample Role Sheet in a Collaborative Activity

Figure 5. Sample Reflection Design

In the deep reflection phase, we posed metacognitive prompts that shift attention from what to why: “Why does GCF take the smallest exponents while LCM takes the largest?” and “When is listing multiples more efficient than using a prime Venn approach?” The reflection sheet provides sentence starters for constructing arguments and space to revise answers after reviewing alternative solutions. The phase concludes with an item that requires students to determine the GCF/ LCM and justify their reasoning.

Develop

This section reports the results of expert validation of the ADE teaching materials for collaborative mathematics learning. Five subject-matter experts evaluated the materials using a validation sheet comprising 40 indicators across five domains. Each indicator was rated on three dimensions: relevance, clarity, and sufficiency using a 4-point scale. The following summary presents domain-level attainment, item-level decisions, and targeted revision recommendations.

Table 4. Domain Level Summary of Expert Validation

Domain	No. of Items	Mean Relevance	Mean Clarity	Mean Sufficiency	Items with I-CVI \geq 0.80
D1. Content & Disciplinary Accuracy	10	3.6	3.3	3.2	10/10
D2. Pedagogy & ADE Components	12	3.7	3.4	3.3	11/12
D3. Language	5	3.4	3.4	3.3	5/5
D4. Presentation & Design	7	3.0	3.0	2.8	5/7
D5. Assessment	6	2.9	3.0	2.7	4/6
TOTAL	40	3.34	3.22	3.06	33/40

Overall, the top two domains (D1 and D2) represent the material's core strengths. The mean Relevance scores indicate that the mathematical concepts/procedures and the ADE strategies are well targeted. Even so, the mean Clarity and Sufficiency scores suggest minor strengthening is needed for stepwise examples and time estimates per activity. Domain D3 is judged adequate which wording is clear and does not hinder comprehension, so remaining refinements are largely cosmetic. The areas requiring the most attention are D4 and D5. For D4, visuals, typographic hierarchy, content segmentation, and accessibility should be made more explicit. D5 is the weakest, signaling a gap in assessment: priority revisions include adding a complete assessment package with scoring criteria, aligning tasks with performance indicators, and explicitly flagging higher-order thinking indicators. In total, 33 of 40 items exceeded the $I-CVI \geq 0.80$ threshold, indicating the instrument is acceptable with focused improvements in assessment and presentation design. Table 5 presents the distribution of I-CVI by category and the S-CVI summary for the overall validation sheet.

Table 5. Distribution of I-CVI Categories and S-CVI Summary

I-CVI Category	Definition (5-expert panel)	Number of items (n)	Proportion of total (40)
1.00	5/5 experts rate 3–4	24	60%
0.80	4/5 experts rate 3–4	9	22.5%
0.60	3/5 experts rate 3–4	7	17.5%
	Total	40	100%

Most items achieved $I-CVI = 1.00$, indicating that the majority were judged relevant by all five experts. The $S-CVI/Ave = 0.885$ reflects high overall content validity, whereas $S-CVI/UA = 0.60$ shows that six out of ten items attained universal agreement. Overall, the instrument is acceptable, with minor revisions focused on items in the 0.60 category. Below, we present the list of items with $I-CVI = 0.60$ together with experts' condensed feedback and planned improvements. Table 6 is intended as a targeted revision guide particularly for assessment and accessibility to ensure each item reaches $I-CVI \geq 0.80$ and to raise the instrument's S-CVI overall.

Table 6. Summary of Expert Feedback and Improvement Plan

No	Indicator	I-CVI	Expert Feedback	Improvement Plan
31	Accessibility	0.60	Overreliance on color; font size is small.	Improve contrast and increase font size.
38	Summative assessment	0.60	Content coverage and construct validity are unclear; few sample items.	Build a summative item bank (min. 12 items: 6 routine, 6 HOTS).
39	Rubric	0.60	Criteria and performance levels are unclear; difficult to assess collaborative processes.	Develop a collaboration rubric (clear criteria and levels).
40	Measurable HOTS indicators	0.60	HOTS are not stated operationally or measurably.	Formulate operational, measurable HOTS indicators.

The revisions were implemented as planned and are consistent with the content-validity results; accordingly, the subsequent phase focused on analyzing students' responses to the practicality of the materials. The following recap reports the Percentage of Maximum Score by dimension and its category, providing corroborating evidence that complements the expert-validation findings.

Table 7. Students' Responses to the Teaching Materials

Dimension	Percentage of Maximum Score	Category
Usability	90	Very Practical
Clarity & Examples	89	Very Practical
Time Efficiency	94	Very Practical
Engagement & Motivation	83	Practical
Collaboration	91	Very Practical
Assessment & Feedback	73	Practical
Satisfaction & Intention to Use	95	Very Practical

Aligned with the expert-validation results, student responses indicate that the materials are perceived as very practical on several dimensions, while engagement, motivation, and assessment/feedback are practical yet still amenable to improvement. As a follow-up to the practicality findings, the next section presents the field trial results to evaluate the effectiveness of ADE in collaborative mathematics learning. The descriptive statistics of student learning outcomes from this field implementation are reported below as an initial portrait of effectiveness.

Table 8. Descriptive Statistics of Students' Learning Outcomes

Group	Mean	Std. Deviation	Minimum	Maximum	N-Gain
Pretest	26,55	9,73	10,0	45,0	0,78
Posttes	84,31	10,91	60,0	100,0	

The summary in Table 8 shows a marked surge in performance following the use of the teaching materials. The mean achievement increased sharply while the score dispersion remained moderate, and even the lowest post-instruction score exceeded the highest pre-instruction score. Overall, these outcomes align with a high-category N-Gain, indicating the effectiveness of the materials in improving student learning. Before conducting mean-

difference tests to evaluate effectiveness, normality and homogeneity of variance were examined to ensure the assumptions of parametric analysis were met. The results of these preliminary tests are presented below.

Table 9. Tests of Normality				Table 10. Test of Homogeneity of Variance				
Shapiro-Wilk				Levene	df1	df2	Sig.	
Group	Statistic	df	Sig.	Statistic				
Pretest	.936	29	.080	Based on	.186	1	56	0.668
Posttest	.942	29	.115	Mean				

The normality tests indicate that the pretest and posttest distributions do not differ significantly from normal ($p = 0.080$ and $p = 0.115$; > 0.05), thus the normality assumption is satisfied. The homogeneity of variance test ($p = 0.668$; > 0.05) likewise shows that group variances are equivalent. Given these assumptions are met, the following presents the results of the paired-samples t-test to assess differences between the pretest and posttest means.

Table 11. Paired Samples Test Learning Outcomes Data				
Mean	Std. Deviation	t	df	Sig.(2-tailed)
-57.75862	13.86067	-22,44	28	.000

The paired-samples t-test showed a significant improvement from pre- to post-implementation of the ADE teaching materials.

Dissemination

In the dissemination phase, all steps were completed ensuring the materials were documented, distributed, and ready for adoption. First, the team finalized a ready to use package in both print and digital formats. Second, intellectual property registration was submitted through the official channel, with all supporting documents uploaded and recorded as evidence of protection.

Discussion

The findings address the research objective by demonstrating that ADE-based materials for GCF–LCM are valid, practical, and effective. Content validity reached a high level with universal agreement on most items, while targeted revisions in assessment and accessibility closed the identified gaps. Student response data positioned the materials from “practical” to “very practical” on usability, clarity, time efficiency, collaboration, and satisfaction coherent with the ADE design that sequences experience, reflection, conceptualization, and application. Learning outcomes rose markedly in the field trial, indicating that the integration of collaborative problem solving and formative feedback supports deeper understanding beyond procedural recall. These results align with recent evidence that active learning improves performance and narrows gaps (Theobald et al., 2020; Ting et al., 2023), that collaborative/ cooperative learning enhances achievement and attitudes when roles and accountability are explicit (Keramati & Gillies, 2022; Ridwan & Hadi, 2022), and that deep learning thrives when assessment emphasizes reasoning and reflection rather than reproduction (Min et al., 2020; Shin et al., 2022).

The study contributes an integrated, classroom-ready package module, teacher guide with collaborative scenarios, rubrics, and an item bank that operationalizes HOTS

within a coherent ADE sequence, offering a practical bridge between policy aspirations and classroom realities in mathematics education. For practice, teachers can: conduct brief diagnostic checks to surface prerequisites and misconceptions, use formative rubrics during group work to guide reasoning and collaboration, and end lessons with structured reflection to consolidate conceptual depth. Limitations include a single-site implementation, limited sessions (three meetings), and a focus on one content area (GCF–LCM); future research should test multi-topic, multi-school replications, longer implementations, and comparative designs to isolate active, deep, and collaborative components. Further work can also examine equity impacts (e.g., gender or prior-attainment subgroups) given evidence that active learning can reduce achievement gaps (Clark, 2023; Di Tommaso et al., 2024). Overall, the study provides theoretically grounded and empirically supported guidance for designing mathematics materials that activate participation, deepen understanding, and structure collaboration in ways that are feasible for everyday classrooms.

CONCLUSION

This study concludes that the Active Deep Experience (ADE) based mathematics material for greatest common factor and least common multiple is valid, practical, and effective for collaborative classroom use. The Content validity of the material was high, with only minor revisions needed for assessment and accessibility. Student responses consistently indicated that the material was practical, efficient, and conducive to collaboration. Furthermore, in the field trial showed a significant improvement in learning outcomes, confirming the effectiveness of the material. These conclusions are based on expert validation, student feedback, and pretest-posttest results, without inferring beyond the observed evidence. To implement the material in schools, the finalized package module, teacher guide with collaborative scenarios, rubrics and item bank can be adopted. It is important for teachers to prioritize timely and specific feedback practices and maintain accessibility standards. Teachers are also integrate brief diagnostic checks at the beginning of lessons, use formative rubrics during group work, and end with targeted reflections to strengthen transfer of learning. To scale the material, it can be replicated in adjacent topics by following ADE's core sequence of experience, reflection, conceptualization, and application, along with explicit roles and accountability. Regular feedback from classroom cycles can be used to fine-tune assessment prompts and media navigation, ensuring sustained use and adaptation in diverse contexts.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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