

The Effect of Critical-Thinking-Oriented Instruction on Grade 5 Students' Learning Outcomes in Decimals

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ABSTRACT: This study provides a preliminary evaluation of the effects of a critical-thinking-oriented instructional approach on Grade 5 students' performance on decimal tasks. The approach comprised three groups of activities: using errors as learning opportunities; exchanging ideas, discussing, and evaluating solution methods; and engaging in self- and peer assessment. A quasi-experimental design combining quantitative and qualitative data was employed with 138 students from four classes at two primary schools in Quang Ninh Province. The two experimental classes, comprising 69 students, participated in these activities, whereas the two control classes, also comprising 69 students, studied the same content for the same amount of time through conventional classroom instruction. The post-intervention test results showed that the experimental group achieved a mean score of 7.75, compared with 6.91 for the control group, with an estimated medium effect size (Cohen's $d = 0.62$). Classroom observations and student work indicated that students in the experimental classes had more opportunities to identify errors, provide reasons, evaluate solution methods, and revise their work. The findings provide initial evidence of the feasibility of integrating critical-thinking-oriented activities into the teaching of decimals. Because only a small number of classes participated and no standardized measure of critical thinking was used, the findings should be interpreted within the scope of the study sample.

KEYWORDS: critical thinking; decimals; learning from errors; mathematical discussion; primary education

1. INTRODUCTION

In primary mathematics education, students need to develop not only computational skills but also the ability to examine the reasonableness of results, explain their solution methods, and make revisions when errors are identified. These activities are associated with critical thinking, understood as purposeful and reflective thinking aimed at making judgments based on appropriate evidence (Ennis, 1987; Facione, 2023). In mathematics classrooms, critical thinking may be manifested when students identify errors in a solution, provide mathematical justification for their evaluations, compare alternative approaches, and verify results.

The Grade 5 topic of decimals offers many opportunities for organizing such activities. Learning decimals requires students to understand place value, relationships among place-value positions, numerical magnitude, and the meanings of operations. However, students often inappropriately apply their knowledge of whole numbers to decimals, for example, by assuming that a decimal with more digits after the decimal point is always greater or by treating the decimal point as a merely formal symbol. Moloney and Stacey (1997) showed that misconceptions about decimal notation can persist for many years when instruction primarily emphasizes rules and procedures. Therefore, student errors are not simply outcomes to be corrected; they can also serve as learning resources through which students analyze and reconstruct their understanding.

Borasi (1994) proposed using errors as starting points for mathematical inquiry. When students are required to identify where an error occurs, explain why it is incorrect, and determine how it can be corrected, they must draw on knowledge as evidence rather than merely accept an answer. Mathematical discussion also provides opportunities for students to present, listen to, and evaluate different solution methods. Self-assessment and peer assessment further support this process by prompting students to review their work, identify aspects requiring revision, and use feedback to improve their learning (Black & Wiliam, 1998; Topping, 2009).

Although critical thinking is regarded as an important educational orientation, its translation into specific activities in primary mathematics classrooms remains limited. Research on decimals has often focused on describing errors or proposing ways to develop concepts; relatively few studies have systematically combined learning from errors, discussion of solution methods, and assessment for learning within the same instructional process. In Vietnam, the emphasis on developing mathematical thinking and reasoning in the 2018 General Education Curriculum further highlights the need to examine forms of classroom organization that can be implemented under ordinary classroom conditions (Ministry of Education and Training, 2018).

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This study provides a preliminary evaluation of an instructional approach integrating three groups of activities: using errors as learning opportunities; exchanging ideas, discussing, and evaluating solution methods; and engaging in self- and peer assessment. The study addressed the following two research questions:

- How does teaching decimals through activities involving the analysis and correction of errors, discussion and evaluation of solution methods, and self- and peer assessment affect Grade 5 students' learning outcomes compared with conventional instruction?
- What manifestations of critical thinking do Grade 5 students demonstrate while participating in these learning activities?

2. THEORETICAL FRAMEWORK AND INSTRUCTIONAL APPROACH

2.1. Manifestations of critical thinking in Grade 5 mathematics learning

Critical thinking encompasses the skills of interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 2023). However, these components need to be specified in relation to the content and learners' age. For Grade 5 students, this study did not seek to assess critical thinking as a general psychological capacity; instead, it focused on behaviors observable during the completion of mathematical tasks: (1) identifying an incorrect or unreasonable element; (2) providing reasons based on previously learned knowledge; (3) evaluating and comparing solution methods; and (4) checking, correcting, or revising one's work. This operationalization connects critical thinking to specific learning activities while remaining appropriate to primary students' linguistic and cognitive abilities.

2.2. Decimals as a context for developing critical thinking

Learning decimals requires students to move from their experience with whole numbers to a representational system structured by place value on both sides of the decimal point. Errors such as comparing 3.45 and 3.5 by comparing 45 with 5, or stating that 4.5×10 equals 4.50, indicate that students may mechanically apply familiar rules without checking the meaning of the result. Tasks that require students to estimate magnitude, compare multiple representations, evaluate solutions, and explain the causes of errors encourage them to attend to the nature of numbers and operations. Learning decimals then becomes a process of analysis and verification rather than merely memorizing rules for moving the decimal point.

2.3. Three components of the instructional approach

The instructional approach did not treat the three components as separate interventions; rather, they functioned as mutually supportive elements. Using errors as learning opportunities provided material for students to analyze; discussion and evaluation helped them articulate their reasoning and engage with alternative ways of thinking; and self- and peer assessment enabled them to use feedback to review and revise their work.

Table 1. Components of the instructional approach

Component	Student activities	Intended manifestations
Using errors as learning opportunities	Examine student work; identify errors; explain their causes; propose corrections	Identification, analysis, and verification
Discussing and evaluating solution methods	Present solutions; ask questions; compare methods; explain agreement or the need for reconsideration	Explanation, evaluation, and reasoning
Self-assessment and peer assessment	Compare work with requirements; evaluate one's own and peers' work; receive feedback; revise	Self-checking and self-regulation

In each lesson, the teacher selected one or more components appropriate to the objectives and content; all three components did not necessarily have to be used simultaneously. Questions were phrased concisely, for example: "Which part is correct or incorrect?", "What knowledge do you use to support your evaluation?", "Is there another solution method?", and "How will you revise your work?" The teacher selected the situations, facilitated discussion, and clarified mathematical knowledge, while the central focus remained on students' processes of examination and explanation.

3. RESEARCH METHODS

3.1. Research design and participants

The study employed a quasi-experimental design with intact classes and combined quantitative and qualitative data. The intervention was conducted during the second semester of the 2025-2026 academic year at Ha Long Primary School and Ha Lam Primary School in Quang Ninh Province. At each school, one class was selected as the experimental class and one as the control class. A total of 138 Grade 5 students participated, with 69 students in each group. Classes within the same school followed the same content, instructional time, and schedule.

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Table 2. Distribution of student participants

School	Experimental group	Control group	Total
Ha Long Primary School	35	35	70
Ha Lam Primary School	34	34	68
Total	69	69	138

3.2. Implementation of the instructional intervention

In the experimental classes, teachers integrated the three groups of activities into instruction on decimals and operations with decimals. The tasks included evaluating erroneous work, explaining the causes of errors, comparing solution methods, checking the reasonableness of results, and using questions or short worksheets for self-assessment and peer assessment. For example, when presented with the statement $4.5 \times 10 = 4.50$, students had to determine whether it was correct, explain why 4.50 is still equal to 4.5, and correct the result. In tasks involving measurement unit conversions or word problems, students worked in pairs or groups, presented their solution methods, and provided feedback on the work of other groups.

In the control classes, teachers taught the same content for the same amount of time according to the schools' instructional plans. Students received full instruction and practice; however, activities involving error identification, evaluation of solution methods, self-assessment, and peer assessment were not implemented as a deliberate and systematic framework. Because the three components were used in combination within the same instructional process, the study examined the effect of the overall approach and did not determine the separate effect of each component.

3.3. Data collection instruments

Students' results on the periodic mathematics assessment at the end of Semester 1 were used to describe the initial comparability of the classes within each school. These results did not constitute a pre-intervention measure of critical thinking and were not directly compared with the post-intervention test to calculate gain scores.

After the intervention, all four classes completed the same test, scored on a 10-point scale. The test included tasks involving operations with decimals, measurement unit conversions, applications in word problems, evaluation of a statement, and explanation of the reasoning. The classes completed the test under the same conditions, and all responses were scored using the same guidelines. The results were summarized in terms of means, standard deviations, and achievement levels.

Qualitative data were collected through classroom observations and analysis of selected student work, including worksheets for evaluating solutions, error-correction tasks, self-assessment forms, and peer-assessment forms. Observations focused on four manifestations: identifying an error; providing a reason; discussing and evaluating solution methods; and checking and revising one's work. The qualitative evidence was used to clarify the learning process and did not replace the test results.

3.4. Data analysis

Quantitative data were analyzed using descriptive statistics and comparisons of post-intervention test scores. Based on the aggregated data, Welch's t-test and Cohen's d were used to estimate the magnitude of the difference between the two groups. Because the intervention was assigned at the class level and the study included only four classes, the results of statistical testing at the student level were treated as exploratory evidence, and conclusions were limited to the study sample. Observation data and student work were organized according to the four categories of manifestations specified in the theoretical framework.

4. RESULTS

4.1. Baseline learning outcomes

The end-of-Semester 1 test scores were relatively similar for the classes within each school. At Ha Long Primary School, the experimental class had a mean score of 5.96, while the control class had a mean score of 6.01. At Ha Lam Primary School, the corresponding values were 5.92 and 5.99. The standard deviations of the four classes ranged from 1.78 to 1.82. These results indicate that each pair of classes had relatively comparable initial mathematics learning outcomes; however, they were not used to establish students' initial levels of critical thinking.

4.2. Post-intervention test results

Table 3. Post-intervention test results

School	Group	n	Mean	Standard deviation	Completed well	Completed	Not completed
Ha Long	Experimental	35	7.72	1.26	21	13	1
Ha Long	Control	35	6.88	1.48	16	16	3

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School	Group	n	Mean	Standard deviation	Completed well	Completed	Not completed
Ha Lam	Experimental	34	7.78	1.23	20	13	1
Ha Lam	Control	34	6.94	1.46	15	16	3
Total	Experimental	69	7.75	1.25	41	26	2
Total	Control	69	6.91	1.47	31	32	6

Table 3 shows the same pattern at both schools. At Ha Long Primary School, the experimental class's mean score was 0.84 points higher than that of the control class; at Ha Lam Primary School, the difference was also 0.84 points. Across the full sample, the experimental group achieved a mean score of 7.75, compared with 6.91 for the control group. The mean difference was 0.84 points, with an estimated 95% confidence interval from 0.38 to 1.30 points. Welch's t-test at the student level yielded $t(132.58) = 3.62$, $p < 0.001$. Cohen's d was 0.62, indicating a medium-sized difference.

The distribution of achievement levels also favored the experimental group. In this group, 41 of 69 students (59.4%) reached the "Completed well" level, compared with 31 of 69 students (44.9%) in the control group. The number of students at the "Not completed" level was 2 in the experimental group, lower than the 6 students in the control group. However, because the intervention was implemented at the class level and only two classes were included in each condition, the statistical results should be interpreted as initial evidence rather than as broadly generalizable causal estimates.

4.3. Manifestations related to critical thinking

Identifying errors and checking reasonableness. During a warm-up activity in a lesson on multiplying decimals by 10, 100, and 1,000 and by 0.1, 0.01, and 0.001, the teacher presented the calculation $4.5 \times 10 = 4.50$. Many students recognized that 4.50 has the same value as 4.5 and therefore could not be the result of multiplying a positive number by 10. Instead of merely applying the rule for moving the decimal point, students used numerical magnitude to check the result. For the solution $3.2 \times 0.1 = 32$, students pointed out that multiplying by 0.1 should produce a result smaller than the original number.

Providing reasons based on mathematical knowledge. When evaluating incorrect solutions, students did not simply label them "correct" or "incorrect" but began to explain their judgments using place value and relationships among place-value positions. In the task of converting 23.45 kg to grams, students had to clarify why multiplication by 1,000 was required and why the result 2,345 g was incorrect. Asking students to answer the question "What knowledge supports your judgment?" shifted error correction from merely giving an answer to explaining its basis.

Discussing and evaluating solution methods. During group work and gallery-walk activities, students examined the products of other groups, marked points that needed to be reconsidered, and discussed how they could be corrected. Some students initially focused only on the final answer; when asked to evaluate each step, they paid greater attention to the choice of operation, the position of the decimal point, and the consistency between the unit and the answer. The discussion process enabled students to encounter alternative solutions and revise their judgments when presented with more convincing justification.

Self-checking and revision. The self-assessment and peer-assessment forms prompted students to review their understanding of the task requirements, selection of operations, calculations, and verification of results. Evidence from student work showed that some students corrected their errors after consulting guiding questions or receiving peer feedback. Supplementary survey results also showed that 62 of 69 students reported that they frequently identified errors, and 64 of 69 reported that they could explain why a solution was correct or incorrect. These self-reported data reflected students' perceptions of their learning experiences and were not used as a direct measure of critical-thinking development.

5. DISCUSSION

The quantitative results show that students in the experimental group performed better on decimal tasks following the instructional intervention. The difference of 0.84 points was consistent across both schools, and the estimated effect size was medium. This consistency across the two pairs of classes strengthens confidence in the observed pattern, although the number of participating classes was limited. The findings align with the view that mathematics learning is more effective when students explain, evaluate, and use feedback rather than merely practice procedures (Black & Wiliam, 1998; Hattie & Timperley, 2007).

One possible mechanism underlying the results is that using errors as learning opportunities required students to connect rules with mathematical meaning. When evaluating $4.5 \times 10 = 4.50$, students could not simply repeat a procedure; they had to examine the relationship between the magnitudes. This illustrates the value of treating errors as starting points for inquiry rather than merely as signs of failure (Borasi, 1994). This approach is particularly appropriate for decimals because many errors arise from inappropriately extending knowledge of whole numbers to decimals (Moloney & Stacey, 1997).

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Discussing and evaluating solution methods helped students articulate their reasoning more clearly. A mathematical conclusion becomes an object of examination when students must explain why they agree with it, why it should be revised, or which verification method can confirm the result. Self-assessment and peer assessment complement this process by transferring part of the responsibility for checking from the teacher to the students. Feedback is valuable when it helps learners recognize the gap between their current performance and the expected outcome and understand the next action they need to take (Hattie & Timperley, 2007).

The qualitative data showed that the activities provided opportunities for students to demonstrate four behaviors: identifying, explaining, evaluating, and revising. However, the study did not use a standardized measure of critical thinking before and after the intervention. Therefore, the findings do not support the conclusion that students developed critical thinking as a general capacity. A more appropriate contribution of the study is to show that integrating tasks requiring analysis and verification may improve students' performance on decimal tasks while making critical-thinking behaviors more visible during learning.

The study has several limitations. First, the sample comprised only four classes at two schools, and the classes were not randomly assigned. Second, the end-of-Semester 1 scores reflected general mathematics achievement and were not an equivalent pre-intervention measure corresponding to the post-intervention test. Third, the post-intervention test focused on selected decimal tasks related to the intervention content, and complete information about its reliability was not available. Future studies should include more classes, use equivalent pre- and post-intervention measures, develop scoring rubrics for manifestations of reasoning, and examine the retention of the results.

6. CONCLUSION

This study developed and tested a critical-thinking-oriented approach to teaching decimals that incorporated the use of errors as learning opportunities, discussion and evaluation of solution methods, and self- and peer assessment. Results from the four classes showed that the experimental group achieved higher post-intervention test scores than the control group, with an estimated medium effect size. Classroom observations and student work also indicated that students had opportunities to identify errors, provide reasons, evaluate solution methods, and revise their work. These findings provide initial evidence that critical-thinking-oriented activities can be integrated into the teaching of decimals under ordinary classroom conditions. However, given the sample size, class-level design, and limitations of the assessment instruments, the conclusions should be regarded only as evidence of feasibility and preliminary effects within the scope of this study.

REFERENCES

- 1) Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice*, 5(1), 7–74. <https://doi.org/10.1080/0969595980050102>
- 2) Ministry of Education and Training. (2018). General education curriculum for Mathematics, promulgated together with Circular No. 32/2018/TT-BGDDT.
- 3) Borasi, R. (1994). Capitalizing on errors as “springboards for inquiry”: A teaching experiment. *Journal for Research in Mathematics Education*, 25(2), 166–208. <https://doi.org/10.5951/jresmetheduc.25.2.0166>
- 4) Ennis, R. H. (1987). A conception of critical thinking—with some curriculum suggestions. *APA Newsletter on Teaching Philosophy*, Summer, 1–5.
- 5) Facione, P. A. (2023). Critical thinking: What it is and why it counts (2023 update). Insight Assessment.
- 6) Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, 77(1), 81–112. <https://doi.org/10.3102/003465430298487>
- 7) Lipman, M. (2003). *Thinking in education* (2nd ed.). Cambridge University Press.
- 8) Moloney, K., & Stacey, K. (1997). Changes with age in students' conceptions of decimal notation. *Mathematics Education Research Journal*, 9, 25–38. <https://doi.org/10.1007/BF03217300>
- 9) National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. NCTM.
- 10) Topping, K. J. (2009). Peer assessment. *Theory Into Practice*, 48(1), 20–27. <https://doi.org/10.1080/00405840802577569>



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