

Enhancing Fraction Problem-Solving Skills through the PISA-Based Design Thinking Process for Grade 5 Students

Ratchaneekorn Wipha^a and Wannatida Yonwilad^{b*}

^{ab}*Bachelor of Education Program in Learning Management Innovation (Mathematics), Faculty of Education and Educational Innovation, Kalasin University, Thailand*

Received: February 25, 2026 Revised: July 01, 2026 Accepted: July 02, 2026

ABSTRACT

This classroom action research asked whether a five-stage design-thinking process empathize, define, brainstorm, prototype, and test could help Grade 5 students solve problems in fraction operations when each stage was tied to one of the three dimensions of mathematical literacy in the PISA framework (formulate, employ, and interpret evaluate). Following the Kemmis and McTaggart model, the teacher-researcher ran the intervention over two cycles, eight hours in all, with 14 purposively selected fifth-graders at a medium-sized school in Somdet District, Kalasin Province, Thailand. The data came from the design-thinking lesson plans, PISA-aligned activity sheets, learning-reflection forms, and two essay tests covering the three dimensions. Three experts judged the instruments suitable (mean appropriateness above 3.51 on a 5-point scale), and item objective congruence was acceptable (IOC above 0.50; test IOC from 0.67 to 1.00). Because the study used only descriptive statistics, the results are reported as observed gains rather than statistically significant effects. From Cycle 1 to Cycle 2 the mean score rose on every dimension formulate from 75.00% to 86.58%, employ from 75.22% to 87.78%, and interpret evaluate from 75.67% to 87.44% while the overall mean climbed from 70.12% to 79.88% and the share of students meeting the proficiency criterion grew from 57.14% to 71.43%. Within this single classroom, then, mapping the design-thinking stages onto the PISA dimensions appears to give fraction instruction a workable structure. Because the design was small and single-group, the findings are exploratory and should be read with caution.

Keywords: Design Thinking Process, PISA Mathematical Literacy, Problem-solving Dimensions, Fraction operations, Classroom Action Research

Introduction

Problem solving sits at the heart of the mathematical competence that 21st century schooling is meant to build. To measure that competence across countries, the Organisation for Economic Co-operation and Development (OECD) created the Programme for International Student Assessment (PISA), which treats mathematical literacy as the ability to frame problems, reason through them, and interpret solutions in real situations (Tririnika et al., 2024). Thailand has accepted that stronger mathematics is essential if its students are to meet international standards (Arpa & Çavur, 2024), yet PISA results keep exposing weaknesses: performance varies with grade level and growth mindset (Setiawan & Kismiantini, 2025) and is pulled by economic, social, and cultural factors such as access to ICT and parental support (Ulkhag, 2024). The framework spans content, cognitive processes, contexts, and competencies (Kir & Aksu, 2024), and it describes mathematical literacy along three dimensions formulate, employ, and interpret evaluation. Strengthening these is a policy priority at home and abroad, since the same literacy underlies both PISA and Thailand's Basic Education Core Curriculum and shapes how far students can reason about and use mathematics in real contexts.

Teaching fifth-grade mathematics in the Somdet District School Group (Kalasin Primary Educational Service Area Office 3), the researcher kept meeting the same trouble with fractions. On a classroom review, more than 60% of the students could not work word problems that add or subtract fractions. They struggled to see equivalent fractions, to find common denominators, and to connect the procedures to everyday life. This echoes a wider pattern among Thai primary students, whose main difficulties appear in expressing equal parts and in addition and subtraction (Dalimunthe & Amelia, 2025). Seen through the PISA dimensions, the problem was not only weak fraction knowledge but

***Corresponding author:** Wannatida Yonwilad, Bachelor of Education Program in Learning Management Innovation (Mathematics), Faculty of Education and Educational Innovation, Kalasin University, Thailand
Email: wantida.yo@ksu.ac.th

weak analysis and application. One task makes this concrete. Asked to combine $\frac{3}{4}$ of one cake with $\frac{5}{8}$ of another and say how much was left after sharing, students faltered at every dimension. In formulation, they tied the situation to fractions only loosely and could not write it as a correct expression. In employ, they tried to add the amounts without first making the denominators alike not seeing, for example, that $\frac{3}{4}$ has to become $\frac{6}{8}$ before it can join $\frac{5}{8}$. In interpret evaluation, they never checked whether the leftover amount made sense.

Misconceptions take hold when teaching is too loosely planned to link the concrete to the abstract (Safira & Harun, 2024). In this classroom the usual lessons were teacher-led demonstration and drill, which did little for conceptual understanding (Dalimunthe & Amelia, 2025). Design thinking was chosen not as a generic active-learning label but because its stages line up with the weaknesses just described. Empathize and define push students toward formulation: they have to read an authentic context and state the problem mathematically. Brainstorm and prototype work on the dimension of employment, as students generate and try out more than one strategy. Test addresses interpret evaluation through checking and justification. Design thinking has produced large effects on mathematical problem solving (Harpeningtyas et al., 2025; Panikar et al., 2025). Even so, although design thinking and the PISA framework have each been studied, few studies map the two onto each other stage by stage for primary fraction learning the gap this study sets out to fill.

Literature review

The review runs along three strands and the links between them: the PISA mathematical-literacy framework and its three dimensions; documented difficulties in fraction learning, and how each map onto a dimension; and the design-thinking process, with the reasoning for aligning its stages with those dimensions. Together the strands lead to the study's conceptual framework, in which each design-thinking stage targets one dimension of fraction problem-solving.

In keeping with the Thai curriculum's 21st century competencies (Dewi et al., 2020), the PISA framework addresses mathematical content as well as cognitive processes, contexts, and competencies (Kir & Aksu, 2024). PISA assessments have proven predictive, with mathematical self-efficacy significantly predicting academic achievement (Huang et al., 2024). The framework operationalizes mathematical literacy on three dimensions: Formulate assesses students' identification of mathematical structures and translation of context into representations (Mufidah et al., 2025); Employ assesses the application of concepts and procedures, with evidence that students who develop both conceptual understanding and procedural fluency show superior long-term retention and transfer (Hidayah & Murti, 2025); and Interpret Evaluate assesses interpretation of results and judgment of reasonableness (Kurino et al., 2024).

Thailand's Basic Education Core Curriculum states that fifth-grade students must add and subtract fractions with like and unlike denominators and apply operations to real-life situations (Dewi et al., 2020), drawing on equivalent fractions, common denominators, procedural fluency, and authentic application. Good instruction moves from concrete manipulatives to symbolic notation (Farra et al., 2024), and multiple representations and collaborative problem solving are essential at this age (Ndiung & Menggo, 2024; Safira & Harun, 2024). Research shows that students often memorize procedures without grasping the underlying relationships, producing recurring computational errors (Indrawati, 2025); difficulty increases with unlike denominators, where students must treat the common denominator as a structural requirement rather than an arbitrary rule (Kontorovich & Zazkis, 2017).

Read against the PISA dimensions, these difficulties are not merely procedural: failing to recognize the underlying structure of a fraction situation is a formulate weakness; relying on memorized steps without conceptual grounding is an employ weakness; and not checking the reasonableness of an answer is an interpret evaluate weakness. This mapping motivates an instructional approach that targets each dimension directly. Design thinking comprises five iterative stages resembling advanced problem-solving processes (Panikar et al., 2025). It recognizes multiple solution pathways, supporting diverse learners (Erenea & Sarmiento, 2025) within a psychologically safe environment (Tririnika et al., 2024). Empathize identifies meaningful contexts and others' viewpoints, driving motivation by

linking ideas to real-world experiences (Erenea & Sarmiento, 2025). Define requires clear articulation of the problem, improving solution accuracy and strategic flexibility (Kir & Aksu, 2024; Rohmah et al., 2023). Brainstorm (Ideate) explores varied methods, fostering computational thinking and cognitive flexibility (Indrawati, 2025; Ndiung & Menggo, 2024). Prototype implements solutions as concrete artifacts, supporting deeper understanding and metacognition. Test compares solutions against the original parameters, enhancing precision through systematic validation and self-reflection (Syifah & Maharbid, 2025). Students move through concrete, iconic, and symbolic representations following Bruner's representation theory (Farra et al., 2024), in an iterative rather than strictly linear process (Panikar et al., 2025).

Conceptually, the study folds the design-thinking stages into the PISA dimensions: empathize and define serve formulate; brainstorm and prototype serve employ through multiple representations and hands-on solutions; and test serves interpret evaluate through checking and reflection (Kir & Aksu, 2024; Panikar et al., 2025). Direct tests of this exact pairing are still scarce, but two lines of evidence make it plausible. First, the five-stage process has been shown to sharpen problem-solving: Nguyễn et al. (2025) found that bringing design thinking into STEM teaching markedly improved high-schoolers' problem-solving, with strong links between stages (define ideate, prototype test) that point to the worth of the iterative cycle. Second, the PISA 2022 framework itself encourages joining structured thinking to mathematical literacy, which is what Rahmawati et al. (2024) did when they built computational thinking into that framework for primary mathematics. Read together, the two suggest it is feasible to embed a structured thinking process in the PISA dimensions the pairing this study works out for design thinking in fraction learning. PISA-Based Design-Thinking Process refers, in this study, to a five-stage instructional sequence (empathize, define, brainstorm, prototype, test) in which each stage is deliberately mapped to a targeted PISA dimension empathize/define to formulate, brainstorm/prototype to employ, and test to interpret evaluate and is enacted iteratively across two action research cycles, with Cycle 2 refined from Cycle 1 reflection data. Fraction Problem Solving Skills refers to students' performance on multi-part word problems involving addition and subtraction of fractions, scored on an analytic rubric across the three PISA dimensions: formulate (recognizing and translating the situation into mathematical form), employ (selecting and executing fraction concepts and procedures), and interpret evaluate (interpreting the result and judging its reasonableness in context), each rated 0-3.

Evidence supports innovative pedagogy in mathematics: problem based learning markedly increased creative thinking and problem solving with large effects (Ndiung & Menggo, 2024); concrete manipulatives outperformed abstract-only instruction in fraction operations (Farra et al., 2024); Realistic Mathematics Education was as effective as or more effective than traditional instruction (Ventistas et al., 2025); and a systematic review reported positive design thinking outcomes across cognitive, affective, and behavioral domains (Yu et al., 2024).

Research Objectives

This action research set out to build Grade 5 students' PISA-based problem-solving in fraction operations across the formulate, employ, and interpret evaluate dimensions through a design-thinking process run over two action-research cycles.

Research methodology

Research Design

This study used a classroom action research design based on the Kemmis and McTaggart cyclical model (Kemmis & McTaggart, 1988). The cycle is iterative, comprising planning, action, observation, and reflection (Efendi et al., 2025). Action research is an empirically supported framework for identifying and resolving genuine classroom problems, empowering teachers to deploy systematic interventions and validate their impact in real teaching learning situations (Cierpiąłowska, 2023). Its cyclical nature allows iterative modification based on data collected over time, making it well suited to evaluating innovative pedagogies such as design-thinking-based learning (Ona & Purwanta, 2025; Torun & Pektaş, 2025).

Participants

The study took place in a medium-sized primary school in the Somdet School District (Kalasin Primary Educational Service Area Office 3), Kalasin Province, Thailand, where the students come from a rural area and a range of backgrounds and where the ordinary classroom had room and materials for group work. Fourteen fifth-graders in the first semester of 2025 took part. They were chosen purposively from earlier surveys of low mathematics achievement and observed trouble with fractions; these criteria reflect general performance rather than tested weakness in the specific PISA dimensions a limitation noted later. A small, purposive group of this kind suits classroom action research, which favors depth and adaptability over size (Amelia et al., 2025).

Data Collection Tools

Four data collection instruments were constructed and validated:

1. Design Thinking Lesson Plans

Four lesson plans, each two hours, carried the five-stage model (Panikar et al., 2025), eight hours in all. Plans 1-2 (Cycle 1) introduced adding and subtracting fractions; Plans 3-4 (Cycle 2) moved to multi-step word problems. Every plan worked from concrete activities (fraction blocks, number lines, paper folding) through visual models (area models, tape diagrams) to symbolic procedures (Farra et al., 2024). The content differed between cycles, but both were assessed with parallel essay tests built on the same rubric and the same three dimensions, so performance was compared on a common construct rather than on identical items.

2. Learning Activity Sheets

Each lesson had one activity sheet, four in all, with four to six tasks tied to the five stages and the PISA dimensions. The prompts scaffolded three moves: (a) restate the situation in the student's own words and name the quantities (formulate); (b) carry out more than one strategy with concrete or visual representations (employ); and (c) check and justify the answer (interpret evaluate). One task, for instance, set out two pizza trays one cut into 8 pieces, plus 3 pieces from a second tray cut into 4 and asked for the total as a fraction, with the method shown. Because the pieces are different sizes, they cannot simply be counted, so the single task draws on all three dimensions: writing the situation as a fraction and noticing the unlike denominators (formulate), rewriting $\frac{3}{4}$ as $\frac{6}{8}$ and adding to get $\frac{8}{8} + \frac{6}{8} = \frac{14}{8} = \frac{7}{4}$ (employ) and judging whether about one and three-quarter trays is reasonable (interpret evaluate).

3. Learning Reflection Forms

A reflection form at the end of each cycle asked students what they had learned, how they had solved problems, and where they had struggled. It mixed 5-point Likert items (engagement, confidence, perceived learning) with open questions. The form did double duty a learning activity that supported metacognition, and a data source on the difficulties students reported in each dimension; the open responses were coded thematically and cross-checked against test scores and field notes.

4. Mathematics Problem-Solving Skill Tests

Two parallel essay tests assessed fraction problem-solving per the PISA framework. Each test was built on a single authentic situation comprising five multi-part items, mapped through a test blueprint (table of specifications) to ten PISA sub-skills across the three dimensions four under formulate (1.1-1.4), three under employ (2.1-2.3), and three under interpret evaluate (3.1-3.3). These tasks reflect key PISA features: an authentic context, the translation of a situation into mathematical form, the use of multiple representations, and an explicit demand to interpret and justify the result. For dimension-level analysis, analytic rubric rated each sub-skill on a 0-3 scale (0 = no evidence, 1 = partial, 2 = adequate, 3 = complete), and each dimension score was reported as the meaning of its sub-skill ratings (Table 3). Separately, each student was assigned an overall test score out of a maximum of 60 points, which was converted to a percentage (Table 2) and classified by the Thai educational quality-level standards (Office of the Basic Education Commission, 2018): $\geq 80\%$ very good, 70-79% good, 60-69% fair, 50-59% needs improvement, $< 50\%$ poor.

5. Expert validation and scoring

Three experts in mathematics education, elementary instruction, and assessment evaluated the lesson plans on six dimensions (content validity, learning management, media/resources, measurement and evaluation, language fit, and integration of design thinking) using a 5-point scale (Srisa-ard, 2010); plans with a mean ≥ 3.51 from all experts were accepted. Activity sheets and tests were examined using the Index of Item-Objective Congruence (IOC: +1, 0, -1), with items ≥ 0.50 considered aligned. All lesson-plan means exceeded 3.51, and all test items exceeded the 0.50 criterion, with IOC values ranging from 0.67 to 1.00. Each essay test was scored by two raters using the analytic rubric; the raters reviewed responses together and resolved discrepancies through discussion to reach a consensus score for each dimension.

Data Collection Procedures

Two complete action-research cycles were carried out in August 2025, each using the Kemmis and McTaggart phases. Table 1 presents the schedule.

Table 1 Organization of learning activities across research cycles

Cycle	Lesson Plans	Subject Matter	Date	Hours
1	1 and 2	Adding and Subtracting Fractions	Aug 14-15, 2025	4
2	3 and 4	Problem-Solving with Adding/Subtracting Fractions	Aug 18-19, 2025	4

Each validated instrument entered the process at a defined point, so that the data-collection procedure was carried out through the data-collection tools rather than separately from them. Before the cycles began, the three experts validated the instruments (expert validation and scoring): the design-thinking lesson plans were rated on the six-dimension 5-point scale, and the activity sheets and the essay tests were screened with the Index of Item-Objective Congruence, so that only validated instruments were taken into the field. Within each cycle, the design-thinking lesson plans (Instrument 1) structured the planning and action phases: the teacher-researcher enacted Plans 1-2 in Cycle 1 and Plans 3-4 in Cycle 2 across four two-hour lessons, each lesson moving through the five stages Empathize (20 min), Define (15 min), Brainstorm (20 min), Prototype (30 min), and Test (15 min) set in real contexts such as recipe scaling, sharing resources, and measurement. As each lesson was taught, students completed the learning activity sheets (Instrument 2), whose four-to-six tasks were tied to the five stages and the three PISA dimensions; these sheets were collected at the end of every lesson and supplied in-process evidence of students' formulation, employ, and interpret evaluate work. Throughout the action and observation phases the researcher recorded field notes and verbal feedback against the staged plans to track how faithfully the five stages were carried out. At the close of each cycle, two end-of-cycle instruments completed the observation and reflection phases: students sat the cycle's mathematics problem-solving skill test (Instrument 4) one of the two parallel essay tests which two raters scored with the analytic rubric to produce the three dimension scores and the 60-point total, and they then completed the learning reflection form (Instrument 3), which combined 5-point Likert items with open questions. The reflection responses, the test results, and the field notes together informed the reflection phase: the difficulty with unlike denominators that surfaced in Cycle 1, seen in students' reflections and work, led to the added scaffolding questions and extra practice built into Cycle 2, which kept the same five stages but leaned harder on the test stage to build interpret evaluate. Fidelity was judged qualitatively from these field notes rather than with a formal checklist or an adherence index, something a later study could add.

Data Analysis Procedures

Data were analysed in two strands, quantitative and qualitative, matched to the two kinds of evidence the instruments produced. The quantitative strand drew on the scores from the two parallel mathematics problem-solving skill tests. Each test was marked by two raters using the analytic rubric, which rated every one of the ten PISA sub-skills on a 0-3 scale; the raters worked through the scripts together and resolved any differences by discussion to reach a consensus score for each sub-skill. Two complementary measures were then derived for every student. The mean rubric level for each PISA dimension (formulate, employ, and interpret evaluate) was obtained by averaging the sub-skill ratings

within that dimension, giving the dimension scores reported on the 0-3 scale in Table 3; and each student's overall performance was expressed as a score out of a maximum of 60 points and converted to a percentage for the overall comparison in Table 2. Because the study used a single intact group of fourteen students with no comparison condition, the analysis was deliberately confined to descriptive statistics: no inferential tests were applied, and the results are read as observed gains rather than as statistically significant effects.

For each cycle, the mean, standard deviation, and percentage of the overall scores were computed, together with the mean percentage for each PISA dimension. Each student's overall percentage was classified by the Thai educational quality-level bands ($\geq 80\%$ very good, 70-79% good, 60-69% fair, 50-59% needs improvement, and below 50% poor), and the proportion of students reaching the proficiency criterion of 70% was recorded. The two cycles were then compared on three things: the mean scores and dimension percentages, the proportion meeting the proficiency criterion, and the distribution of students across the quality-level bands. Throughout, the dimension percentages (meaning rubric levels on the 0-3 scale) and the overall percentages (out of the 60-point total) were kept on separate bases and were not treated as directly comparable.

The qualitative strand drew on the learning activity sheets, the open-ended responses in the learning reflection forms, and the field notes, and followed the interactive model of Miles and Huberman (1984), which moves between data reduction, data display, and conclusion drawing and verification. In the data-reduction phase, the reflective records and open responses were read across both cycles and segmented, and student responses were coded against the three PISA dimensions using the same analytic rubric, so that the qualitative coding and the quantitative scoring shared a common framework. The coded material was then arranged by cycle and by dimension in summary displays, which made recurring patterns visible and allowed them to be grouped into themes. Finally, the emerging themes were checked against the test performance and the field notes a form of triangulation across the three data sources and refined where the sources diverged, so that each theme rested on more than one kind of evidence. This process produced the three themes reported in the qualitative findings and identified the recurring difficulty with unlike denominators that ran through both cycles.

Results

Quantitative Findings

Results are organized by the research objective: developing fifth-graders' fraction problem-solving across the PISA dimensions through design-thinking instruction.

Table 2 Overall performance comparison between cycles

Cycle	N	No. of students scoring full marks	Mean Score	Mean %	SD	Met Criteria
1	14	1	42.07	70.12	11.94	8 (57.14%) - good
2	14	3	47.93	79.88	10.76	10 (71.43%) - good

Table 2 shows overall performance rising from 70.12% in Cycle 1 to 79.88% in Cycle 2, just short of the very-good band; the share meeting the proficiency criterion ($\geq 70\%$) grew from 57.14% (8 students) to 71.43% (10 students).

Table 3 Performance on PISA dimensions by cycle

PISA Dimension	Cycle Mean	1	Cycle 1 %	Cycle Mean	2	Cycle 2 %	Improvement
1. Formulate	2.25/3		75.00%	2.60/3		86.58%	+11.58%
2. Employ	2.26/3		75.22%	2.63/3		87.78%	+12.56%
3. Interpret Evaluate	2.27/3		75.67%	2.62/3		87.44%	+11.77%
Average	2.26/3		75.30%	2.62/3		87.27%	+11.97%

Table 3 shows improvement in all three dimensions from Cycle 1 to Cycle 2. Formulation rose from 75.00% to 86.58%, employment gained the most (75.22% to 87.78%), and interpret evaluation rose from 75.67% to 87.44%. By Cycle 2 every dimension reached the very-good band ($\geq 80\%$), a mean gain of 11.97 percentage points. These dimension figures mean rubric levels on the 0-3 scale from the analytic coding; they sit on a different basis from the 60-point total in Table 2 and are not directly comparable to the overall percentages.

Table 4 Distribution of students by quality level

Quality Level	Score Range	Cycle 1 (n)	Cycle 1 (%)	Cycle 2 (n)	Cycle 2 (%)
Very Good	$\geq 80\%$	7	50.00%	9	64.29%
Good	70-79%	1	7.14%	1	7.14%
Fair	60-69%	2	14.29%	1	7.14%
Needs Improvement	50-59%	1	7.14%	2	14.29%
Poor	$< 50\%$	3	21.43%	1	7.14%

Table 4 shows that the proportion of students at the very-good level increased from 50.00% (7 students) to 64.29% (9 students), while the proportion scoring below 60% decreased from 28.57% (4 students) to 21.43% (3 students). These changes suggest improvements among both higher- and lower-performing students.

Qualitative Findings

The qualitative material came from the researcher's reflective records across both cycles, drawing on stage-by-stage notes and cycle-level logs of problems and solutions. Three themes ran through it: the conditions the design-thinking process needed in order to work, the engagement it built, and the conceptual clarity students described.

The first theme was a growing willingness among students to formulate and share mathematical ideas. In Cycle 1, the records noted that several students were initially reluctant to propose ideas during the define and brainstorm stages and hesitant to present their reasoning to the class. The teacher responded with "write-before-speak" and small-group sharing routines and by praising effort rather than correct answers. By Cycle 2, the corresponding record indicated that this reluctance had narrowed to a smaller group, addressed by reaffirming that "thinking differently is not wrong." This shift aligns with the brainstorm and prototype stages' intended role in helping students generate and voice multiple solution strategies. It matters because willingness to articulate a problem mathematically is a precondition for the kind of formulation the intervention targeted, and the reduction in reluctance across cycles ran alongside the formulate gains the rubric captured.

The second theme concerned on-task engagement and collaborative self-regulation. Both cycles recorded off-task behaviour and slow task completion. The teacher's responses evolved from establishing shared classroom rules and using competitive warm-up activities with positive reinforcement in Cycle 1 toward post-lesson self-reflection prompts (e.g., "today I did well at...") and paired work in Cycle 2, suggesting increasingly self-regulatory routines as students became familiar with the staged structure. This gradual establishment of collaborative and self-regulatory habits appeared to be a necessary condition for the staged process to function, rather than an incidental feature of the classroom context.

Alongside these behavioural routines, the reflection forms revealed a shift in students' affective engagement toward mathematics. Many students expressed that the design-thinking activities made learning more accessible and enjoyable. One student noted, "I like learning this way because it feels fun, not stressful. I can understand the steps because I get to try and fix my mistakes by myself." This suggests that the iterative prototype and test stages helped reduce anxiety and fostered a more positive disposition toward complex fraction operations.

The third theme was a growing conceptual clarity, as students described moving away from memorization toward understanding. A recurring point in their reflections was the move away from abstract memorization toward hands-on understanding. As one student put it, “I understand it now because I don’t just have to memorize the numbers. I can see what the fractions actually mean, and that makes it much easier to solve.” This remark illustrates how the stage-by-stage alignment appeared to help students bridge concrete representations and symbolic mathematical expressions, moving from a surface engagement with procedures toward a more connected understanding of the operations involved.

Across both cycles, the reflective records consistently identified the addition of fractions with unlike denominators as the central mathematical difficulty. This difficulty was addressed at the define stage through analysis of whether denominators were equal and where errors typically arose and revisited at the test stage through the requirement that denominators be made equal before addition could proceed. Its recurrence across both cycles, and its gradual decline in the rubric scores, positioned it as the clearest instance of the intervention targeting a specific conceptual gap rather than general procedural performance.

Discussion

Across the two cycles, every indicator moved in the same direction. Overall performance rose from 70.12% to 79.88%, the proportion of students meeting the proficiency criteria grew from 57.14% to 71.43%, and all three PISA dimensions improved by roughly 11 to 12 percentage points, with employ gaining the most at +12.56 points. Within a single classroom and without a comparison condition, these figures cannot establish causation, but their consistency across dimensions and across the two measurement points is worth taking seriously. A design that targeted each dimension through a specific stage would be expected to produce broadly parallel gains if the alignment was working, and the observed pattern is at least consistent with that expectation, as well as with the theoretical reasoning that design-thinking stages can support PISA-style mathematical literacy (Wulandari et al., 2025).

The employ gain warrants particular attention. Among the three dimensions, employment most directly reflects students’ ability to select and execute fraction procedures, the area in which prior research consistently identifies the deepest difficulties at the primary level (Dalimunthe & Amelia, 2025; Indrawati, 2025). The brainstorm and prototype stages asked students to generate more than one solution strategy and to work through concrete and visual representations before moving to symbolic procedures, following the concrete-to-representational-to-abstract sequence that Farra et al. (2024) found more effective than abstract-only instruction in fraction learning. The fact that the employ dimension responded most strongly is at least consistent with the theoretical reasoning behind the stage alignment, even if the study cannot confirm the mechanism directly.

The formulate gains are similarly interpretable in light of the qualitative record. Students in Cycle 1 were reluctant to articulate their mathematical reading of a problem, and the teacher’s responses, including write-before-speak routines and small-group sharing, were designed to lower that barrier. By Cycle 2 the reluctance had narrowed, and this behavioral shift ran alongside the formulate improvement captured by the rubric. The connection is suggestive rather than conclusive. It points toward a finding that matters for instruction, namely that students who struggle with fraction problems do not always lack procedural knowledge but sometimes lack the disposition and the routine to formulate the problem mathematically in the first place. The define stage, by requiring students to restate the situation and name the quantities before any calculation, may offer one way to address that gap, and it may also help students treat the common denominator as a conceptual necessity rather than an arbitrary procedural rule, as Kontorovich and Zazkis (2017) argue is essential for genuine understanding of unlike denominator operations. Whether the defined stage does so more effectively than other instructional approaches cannot be determined from this study alone.

The interpret and evaluate dimension gained least in absolute terms, though it still rose by 11.77 points and reached the very-good band by Cycle 2. This relative modesty is informative. Interpretation and justification are cognitively demanding and typically the last to consolidate in young learners

(Hidayah & Murti, 2025; Kurino et al., 2024), and eight hours across two cycles may not have been sufficient for students to fully internalize checking as a habitual part of problem-solving rather than an additional task. The test stage addressed this dimension directly, but the qualitative record suggests it was the stage where engagement was most variable and where the teacher's scaffolding was least consistent across lessons. Future designs might allocate more time to this stage or build explicit self-assessment prompts into it to strengthen its impact on this dimension.

The reduction in students scoring below 60%, from 28.57% to 21.43%, is consistent with research suggesting that structured, iterative pedagogies can support lower-performing learners in mixed-ability settings (Putri et al., 2024; Widodo et al., 2025). An important caveat applies here, however. With only 14 students, the movement of one or two individuals shifts that percentage substantially, and no reliable claim about differential effectiveness can be made on this basis. What the pattern does suggest is that the staged routine may have given lower-performing students sufficient structure to engage with problems they would otherwise have avoided, a possibility that warrants systematic investigation with larger samples.

Placed alongside the broader literature, the gains reported here are more modest than those in studies using larger samples or experimental designs (Harpeningtyas et al., 2025; Nguyễn et al., 2025), but they are consistent in direction with meta-analytic evidence supporting design thinking across cognitive, affective, and behavioral outcomes (Yu et al., 2024) and with findings that problem-based and student-centered approaches improve mathematical problem-solving at the primary level (Ndiung & Menggo, 2024). The difference in magnitude is most plausibly a function of duration and design rather than an indication that the approach is less effective. A short, single-group classroom cycle with a small purposive sample is structurally unlikely to produce the effect sizes reported in randomized or quasi-experimental studies, regardless of how well the intervention is implemented. This does not weaken the present findings so much as it clarifies what kind of claim they can support. The study offers a carefully documented account of a theoretically grounded instructional approach producing consistent improvement across a specific set of dimensions in a real classroom, and that constitutes a meaningful contribution at this early stage of research on the design-thinking and PISA pairing in primary mathematics.

A final observation merits consideration. Addition of fractions with unlike denominators was identified as the central mathematical difficulty across both cycles, and it manifested across all three dimensions simultaneously. Students struggled to recognize it as a structural problem rather than a procedural one (formulate), defaulted to adding numerators and denominators separately without converting (employ), and rarely checked whether their answers were plausible (interpret and evaluate). This cross-dimensional character of a single conceptual difficulty is precisely what a dimension-aligned instructional model is built to address, and the decline in unlike denominator errors across cycles, visible in both the rubric scores and the qualitative record, is consistent with the possibility that the staged structure helped students engage with the difficulty more systematically, though this interpretation remains tentative given the study's descriptive and single-group design.

Conclusion

This study set out to explore whether mapping the five stages of design thinking explicitly onto the three PISA problem-solving dimensions could give primary fraction instruction a workable and principled structure. Within this single classroom, the results were encouraging. Overall performance rose from 70.12% to 79.88%, the proportion of students meeting the proficiency criterion grew from 57.14% to 71.43%, and all three dimensions improved consistently across cycles. Formulate rose from 75.00% to 86.58%, employed from 75.22% to 87.78%, and interpret and evaluate from 75.67% to 87.44%, with every dimension reaching the very-good band by Cycle 2. These figures are descriptive, drawn from a small single group, and cannot be read as evidence of causal effect. What they do suggest, more modestly, is that the staged pairing produced consistent and parallel improvement across dimensions within this particular classroom context.

The theoretical contribution of the study lies in the explicitness of the pairing itself. Prior work has applied design thinking to mathematics broadly and has used the PISA framework to diagnose student performance, but the two have rarely been brought together stage by stage for a specific content

domain at the primary level. By treating empathize and defining as entry points into problem formulation, brainstorm and prototype as scaffolds for representational and procedural work, and test as a structured mechanism for interpretation and justification, the study offers a concrete and testable instructional model. The parallel gains across all three dimensions are consistent with the theoretical logic of that model, though with a sample of 14 and no comparison condition, they cannot confirm it. The qualitative record adds some texture: students described moving away from memorization toward understanding, and their growing readiness to articulate mathematical reasoning across cycles is broadly in line with the formulate gains the rubric captured, though this reading remains interpretive.

The practical value of the approach appeared most clearly around unlike denominator addition, which was the persistent difficulty across both cycles. The design-thinking structure addressed it not by adding more drills but by making the conceptual necessity of common denominators visible at the define stage and verifiable at the test stage. Whether this mechanism accounts for the gains cannot be established here, but it points to a plausible reason why a staged routine might suit fraction content specifically, given that fraction errors often reflect weak problem formulation and insufficient checking rather than procedural failure alone. The reduction in students scoring below 60%, from 28.57% to 21.43%, is also worth noting, though with only 14 students the shift of one or two individuals is enough to move that figure considerably, and no strong claim about differential effectiveness can rest on it.

The study's limitations should be bound by how far these conclusions travel. The design was small, single-group, and restricted to eight hours across two cycles; no comparison condition was possible, and novelty, maturation, and repeated-testing effects cannot be ruled out. The cross-cycle comparison assumes broadly parallel test forms whose difficulty was not formally equated. The qualitative record describes instructional process and classroom engagement rather than dimension-level conceptual change in individual student work. These constraints mean the findings are best read as exploratory: they document that the pairing is feasible in an ordinary primary classroom and that it was associated with consistent improvement, not that it caused it or that the same results would appear elsewhere.

Three directions follow with particular priority. The stage-by-stage pairing needs testing under experimental or quasi-experimental conditions with larger and more diverse samples, so that effect size and causal attribution become tractable. Longitudinal designs would establish whether the gains persist and transfer beyond the intervention window. Systematic coding of individual student artifacts within each PISA dimension would also give the qualitative strand the analytic depth it currently lacks. The present study contributes a documented, theoretically grounded starting point: the design-thinking and PISA pairing is coherent, feasible at the primary level, and merits the more rigorous investigation it has not yet received.

References

- Amelia, P., Pendit, S. S. D., Wilade, S., Firmansyah, A., & Isnayanti, A. N. (2025). Visual-enhanced discovery learning: An action research study on improving natural and social sciences learning outcomes in elementary education. *Journal of Innovation and Research in Primary Education*, 4(4), 3346–3355. <https://doi.org/10.56916/jirpe.v4i4.2383>
- Arpa, T., & Çavur, M. (2024). A comparative analysis of machine learning techniques to explore factors affecting mathematics success in developing countries: Turkey, Mexico, Thailand, and Bulgaria case studies. *Journal of Information Systems and Management Research*, 6(2), 24–36. <https://doi.org/10.59940/jismar.1514958>
- Cierpiąłowska, T. (2023). Action research as a path to change in the teaching/learning process. *Multidisciplinary Journal of School Education*, 12(2), 257–275. <https://doi.org/10.35765/mjse.2023.1224.13>
- Dalimunthe, M. W., & Amelia, C. (2025). Analysis of learning difficulties in simple fractions through elementary school class VI fractional card media: Analisis kesulitan belajar matematika pada materi pecahan sederhana melalui media kartu pecahan di kelas VI SD. *Edu Cendikia: Jurnal Ilmiah Kependidikan*, 5(1), 52–61. <https://doi.org/10.47709/educendikia.v5i01.5603>

- Dewi, A. K., Slamet, S. Y., Surya, A., & Syawaludin, A. (2020). Thailand elementary school students' critical thinking skills in mathematics education. *Journal of Physics: Conference Series*, 1511(1), Article 012047. <https://doi.org/10.1088/1742-6596/1511/1/012047>
- Efendi, R., Siswanto, D. H., & Saputra, S. A. (2025). Deep learning approach to teaching multiplication concepts using coin media: Classroom action research in elementary school. *Jurnal Padamu Negeri*, 2(2), 87–97. <https://doi.org/10.69714/xaewmx28>
- Erenea, R. R., & Sarmiento, C. P. (2025). Integrating design thinking into e-learning activities in mathematics for STEM students. *E-Learning and Digital Media*. Advance online publication. <https://doi.org/10.1177/20427530251358511>
- Farra, N. K. A., Belbase, S., Tairab, H., Qablan, A., Opoku, M. P., & Safi, S. K. (2024). Impact of using virtual and concrete manipulatives on students' learning of fractions. *Cogent Education*, 11(1). <https://doi.org/10.1080/2331186X.2024.2379712>
- Harpeningtyas, R. B., Nizaruddin, N., & Dwijayanti, I. (2025). Implementation design thinking in Google Sites with TaRL approach to improve mathematical problem-solving skills. *Mathline: Jurnal Matematika dan Pendidikan Matematika*, 10(4), 893–912. <https://doi.org/10.31943/mathline.v10i4.1029>
- Hidayah, R. N., & Murti, R. C. (2025). Evaluating mathematical problem-solving skills in primary school students: Challenges and insights from Polya's framework. *Al-Ishlah*, 17(3). <https://doi.org/10.35445/alishlah.v17i3.6534>
- Huang, Y., Zhou, Y., Chen, J., & Wu, D. (2024). Applying machine learning and SHAP method to identify key influences on middle-school students' mathematics literacy performance. *Journal of Intelligence*, 12(10), 93. <https://doi.org/10.3390/jintelligence12100093>
- Indrawati, D. (2025). Profiling elementary students' computational thinking in fraction problem-solving: Implications for 21st-century learning. *International Journal of Applied Mathematics*, 38(5), 226–242. <https://doi.org/10.12732/ijam.v38i5.523>
- Kemmis, S., & McTaggart, R. (1988). *The action research planner* (3rd ed.). Deakin University Press.
- Kir, H., & Aksu, H. H. (2024). Evaluation of 7th grade students' mathematical literacy skills according to PISA framework. *Shanlax International Journal of Education*, 13(1), 60–69. <https://doi.org/10.34293/education.v13i1.7778>
- Kontorovich, I., & Zazkis, R. (2017). Mathematical conventions: Revisiting arbitrary and necessary. *For the Learning of Mathematics*, 37(1), 29–34.
- Kurino, Y. D., Herman, T., Turmudi, T., Yonanda, D. A., & Haryanti, Y. D. (2024). Enhancing mathematical problem-solving skills through flipped classrooms and discovery learning: A resilience-based approach for elementary students. *Al-Ishlah*, 16(4). <https://doi.org/10.35445/alishlah.v16i4.6243>
- Miles, M. B., & Huberman, A. M. (1984). *Qualitative data analysis: A sourcebook of new methods*. Sage.
- Mufidah, S., Sudirman, & Muksar, M. (2025). Mathematical literacy performance of junior high school students in solving PISA problems. *Journal of Education Research and Evaluation*, 9(2), 360–371. <https://doi.org/10.23887/jere.v9i2.92677>
- Ndiung, S., & Menggo, S. (2024). Project-based learning in fostering creative thinking and mathematical problem-solving skills: Evidence from primary education in Indonesia. *International Journal of Learning, Teaching and Educational Research*, 23(8), 289–308. <https://doi.org/10.26803/ijlter.23.8.15>
- Nguyễn, L. C., Hoa, H. Q., & Hien, L. H. P. (2025). Integrating design thinking into STEM education: Enhancing problem-solving skills of high school students. *Eurasia Journal of Mathematics, Science and Technology Education*, 21(4), Article em2611. <https://doi.org/10.29333/ejmste/16084>
- Office of the Basic Education Commission. (2018). *Standards for early childhood and basic education*. Ministry of Education. [In Thai]
- Ona, M. G. P., & Purwanta, E. (2025). Enhancing early reading skills through problem-based learning: A classroom action research with students with intellectual disabilities. *Journal of Innovation and Research in Primary Education*, 4(3), 1675–1686. <https://doi.org/10.56916/jirpe.v4i3.1899>
- Panikar, P., Milligan, C., Al Bulushi, A. H., Rizwan, S. M., & Al Balushi, N. (2025). Empowering future innovators: A TRIZ-integrated design thinking approach to engineering prototyping and entrepreneurship in Oman. *International Journal of Learning, Teaching and Educational Research*, 24(2), 322–351. <https://doi.org/10.26803/ijlter.24.2.17>

- Putri, A., Soesilawati, S. A., & Diani, N. (2024). Problem-based learning in improving student learning outcomes in biology learning. *Universal Education Journal of Teaching and Learning*, 1(2), 50–56. <https://doi.org/10.63081/uejtl.v1i2.36>
- Rahmawati, R. D., Sugiman, Wangid, M. N., & Purnomo, Y. W. (2024). Designing model of mathematics instruction based on computational thinking and mathematical thinking for elementary school student. *Mathematics Teaching Research Journal*, 16(1), 143–166.
- Rohmah, L., Rahayu, R., & Fardani, M. A. (2023). How elementary students communicate their mathematical problem solving in writing. *Journal of Innovation and Research in Primary Education*, 2(2), 45–54. <https://doi.org/10.56916/jirpe.v2i2.556>
- Safira, A. F., & Harun, H. (2024). Development of three-tier diagnostic test to measure misconceptions of grade 5 students about fractions. *JETL (Journal of Education Teaching and Learning)*, 9(2), 149. <https://doi.org/10.26737/jetl.v9i2.5857>
- Setiawan, E. P., & Kismiantini, K. (2025). Students' grades, growth mindset, and mathematics performance: PISA results in Southeast Asia and Australia. *Journal of Mathematics and Science Teacher*, 5(1), Article em076. <https://doi.org/10.29333/mathsciteacher/15999>
- Srisa-ard, B. (2010). *Research for problem solving and learner development* (3rd ed.). Suweerisan. [In Thai]
- Syifah, D. N., & Maharbid, D. A. (2025). Discovery learning and mathematical problem-solving: Evidence from elementary education classrooms. *Jurnal Pendidikan Matematika*, 16(2), 154–163. <https://doi.org/10.36709/jpm.v16i2.304>
- Torun, B., & Pektaş, M. (2025). An action research on the utilization of formative assessment components in online environments in science education. *Kastamonu Eğitim Dergisi*, 33(2), 372–388. <https://doi.org/10.24106/kefdergi.1683488>
- Tririnika, Y., Suryadi, I., & Slamet, I. (2024). In-depth analysis of students' mathematical problem-solving skills: Influence factors motivation and effective teaching strategies. *Al-Ishlah*, 16(3). <https://doi.org/10.35445/alishlah.v16i3.5474>
- Ulkhaq, M. M. (2024). Investigating the impact of ICT on mathematics performance among students in South-East Asian countries: Insights from PISA 2018 data. *Annales Universitatis Paedagogicae Cracoviensis: Studia ad Didacticam Mathematicae Pertinentia*, 16, 69–84. <https://doi.org/10.24917/20809751.16.5>
- Ventistas, G., Ventista, O. M., & Tsani, P. (2025). The impact of realistic mathematics education on secondary school students' problem-solving skills: A comparative evaluation study. *Research in Mathematics Education*, 27(3), 437–461. <https://doi.org/10.1080/14794802.2024.2306633>
- Widodo, S. T., Nisa, A. F., & Zulfiati, H. M. (2025). The effect of problem-based learning model with TaRL approach on natural and social sciences learning outcomes and critical thinking skills in elementary school. *Jurnal Cakrawala Pendas*, 11(3), 750–762. <https://doi.org/10.31949/jcp.v11i3.13582>
- Wulandari, R. G., Purwosetiyono, F. X. D., & Nizaruddin, N. (2025). Exploration of creative problem-solving learning based on design thinking with HOTS questions to improve students' numeracy. *Kontinu: Jurnal Penelitian Didaktik Matematika*, 9(2), 267–288. <https://doi.org/10.30659/kontinu.9.2.267-288>
- Yu, Q., Yu, K., & Lin, R. (2024). A meta-analysis of the effects of design thinking on student learning. *Humanities & Social Sciences Communications*, 11(1). <https://doi.org/10.1057/s41599-024-03237-5>