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Improving Mathematical Problem-Solving Ability Ahrough Numeracy-Based Quizzes

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ABSTRACT

Numeracy enables learners to access, interpret, use, and communicate mathematical information in meaningful contexts. This study examined the achievement pattern of contextual problem-solving quizzes in Grade XI mathematics, specifically linear programming. A descriptive qualitative design involved 36 students of Class XI MIPA 4 at SMA Negeri 1 Gresik during the 2021/2022 academic year. Data were collected through four numeracy-based quizzes and interviews. The quizzes consisted of contextual constructed-response tasks analyzed using four problem-solving indicators: understanding the problem, devising a plan, carrying out the plan, and looking back. Mean scores were 8.34 for Quiz 1, 8.72 for Quiz 2, 8.66 for Quiz 3, and 8.91 for Quiz 4. The overall pattern therefore increased from the first to the fourth quiz, although a slight decline occurred in Quiz 3. Interview evidence indicated that inaccuracies in drawing the feasible region contributed to some lower scores. The findings suggest that repeated contextual quizzes can provide formative opportunities for students to articulate mathematical models, select solution strategies, execute procedures, and verify results. Because the study used one class without a comparison group, the score pattern should be interpreted descriptively rather than as causal evidence. Numeracy-oriented contextual quizzes can be used as a practical classroom assessment strategy to strengthen problem-solving habits in linear programming.

Keywords: contextual problems; formative assessment; linear programming; numeracy; problem solving

INTRODUCTION

Numeracy is increasingly understood as the capacity to use mathematical knowledge purposefully in real-life situations rather than merely perform routine calculations. Contemporary frameworks emphasize reasoning, representation, interpretation, decision making, and communication across personal, social, and occupational contexts (Geiger et al., 2015; Tout, 2020; OECD, 2023; Stacey, 2015). In school mathematics, this orientation aligns with mathematical literacy and problem solving, because students must identify relevant information, formulate a mathematical model, select procedures, interpret results, and judge whether an answer is reasonable (Jablonka, 2015; Kaiser & Sriraman, 2006; Stillman et al., 2015; Verschaffel et al., 2020).

Problem solving is central to mathematics learning and is especially important in linear programming, where students translate contextual constraints into inequalities, represent feasible regions, and optimize an

objective function. Successful performance requires conceptual understanding, strategic competence, procedural fluency, and reflective checking (Schoenfeld, 2016; Liljedahl et al., 2016; Rott, 2020; Verschaffel et al., 2020). Context-rich tasks can also help learners connect symbolic mathematics with situations involving resources, costs, production, and decision making (Blum, 2015; Schukajlow et al., 2018; Geiger et al., 2018).

Assessment can support this learning when it is used formatively and repeatedly. Low-stakes quizzes provide opportunities for retrieval, feedback, self-monitoring, and adjustment of learning strategies (Roediger & Karpicke, 2006; Adesope et al., 2017; Yang et al., 2021; Pan & Rickard, 2018). Formative assessment is most productive when evidence of student thinking is used to identify misconceptions and guide subsequent instruction (Black & Wiliam, 2009; Wiliam, 2011; Wisniewski et al., 2020; Schildkamp et al., 2020). In mathematics, constructed-response quizzes are particularly useful because they reveal not only final answers but also modeling decisions and intermediate reasoning (Bennett, 2011; Kingston & Nash, 2011; Rakoczy et al., 2019).

At SMA Negeri 1 Gresik, linear-programming contextual problems had been identified as challenging for students. The present study therefore implemented four numeracy-based contextual quizzes at the end of mathematics lessons. The study aimed to describe students' quiz achievement and their problem-solving processes across the four tasks. Rather than claiming experimental effectiveness, the analysis focuses on the observed score pattern and evidence of the four problem-solving stages in students' work and interviews.

LITERATURE REVIEW

Numeracy and Mathematical Literacy

Numeracy involves the disposition and capacity to engage with quantitative information in context. It includes interpreting representations, estimating, calculating, reasoning with quantities, and communicating conclusions (Tout, 2020; Geiger et al., 2015; OECD, 2023). Mathematical literacy similarly emphasizes formulating, employing, and interpreting mathematics in varied contexts. These constructs are not identical to school mathematics content, but they depend on conceptual knowledge and the ability to mobilize that knowledge flexibly (Stacey, 2015; Jablonka, 2015; Gal et al., 2020; Hoogland et al., 2018). Research on numeracy education therefore recommends authentic tasks, multiple representations, explicit reasoning, and opportunities to justify decisions (Geiger et al., 2018; Tout et al., 2021; Grotlüschen et al., 2020).

Contextual Mathematical Problem Solving

Polya's four phases—understanding the problem, devising a plan, carrying out the plan, and looking back—remain a useful heuristic for analyzing students' solution processes (Polya, 1971). Later work has

emphasized metacognition, representation, strategy selection, and monitoring as integral components of expert problem solving (Schoenfeld, 2016; Rott, 2020; Verschaffel et al., 2020). Contextual and modeling problems add another layer because students must move between the real situation and a mathematical representation (Blum, 2015; Kaiser & Sriraman, 2006; Schukajlow et al., 2018). Productive struggle, carefully designed scaffolding, and discussion of alternative strategies can improve students' capacity to reason through non-routine tasks (Kapur, 2016; Hiebert & Grouws, 2007; Loibl et al., 2017; Fyfe et al., 2014).

Quizzes as Formative Assessment

Frequent low-stakes testing can enhance retention and make learning gaps visible to both students and teachers. Meta-analytic evidence supports practice testing and retrieval practice across educational settings, particularly when quizzes are accompanied by feedback (Adesope et al., 2017; Rowland, 2014; Yang et al., 2021; Pan & Rickard, 2018). Feedback is most useful when it is timely, specific, and linked to the learning goal and next steps (Hattie & Timperley, 2007; Wisniewski et al., 2020; Lipnevich & Panadero, 2021). In mathematics, formative assessment can promote self-regulation and conceptual development when students are asked to explain reasoning rather than only select an answer (Rakoczy et al., 2019; Panadero et al., 2018; Andrade, 2019; Schildkamp et al., 2020).

METHODS

Research Design and Participants

The study used a descriptive qualitative approach. Participants were 36 students of Class XI MIPA 4 at SMA Negeri 1 Gresik in the first semester of the 2021/2022 academic year. Participants were selected purposively because the class was studying linear programming and was the instructional setting in which the numeracy-oriented quizzes were implemented. The design describes classroom evidence and does not include randomization, a control group, or a pretest-posttest comparison.

Instruments and Data Collection

Data were obtained from four contextual constructed-response quizzes and interviews. Quiz items were adapted from Indonesian National Examination materials and validated by two certified mathematics teachers. Interviews were used to clarify problem-solving indicators that were not fully visible in written work. Student solutions were analyzed using four indicators adapted from Polya: understanding the problem, planning a solution, carrying out the plan, and checking the completed solution.

Table 1. Problem-Solving Quiz Scoring Framework

Indicator	Maximum score	Evidence expected
Understanding the problem	2	Interprets the problem completely and identifies relevant information.
Planning a solution	4	Develops a valid and sufficiently complete mathematical plan.
Carrying out the plan	2	Executes appropriate procedures and obtains a correct result.
Looking back	2	Checks the process and verifies the reasonableness of the solution.
Total	10	Overall contextual problem-solving performance.

Quiz Contexts and Analysis

Quiz 1 used a wet-bread and dry-bread production context; Quiz 2 concerned two fertilizer types; Quiz 3 concerned men's and women's shoes; and Quiz 4 concerned liquid and granular fertilizers. These tasks progressively required students to recognize a linear-programming situation, formulate a model, determine a feasible region, and identify an optimum solution. Scores were summarized descriptively using the class mean for each quiz. Written solutions and interview explanations were then interpreted according to the four problem-solving indicators. No inferential test was used because the purpose was descriptive and the design did not establish an experimental counterfactual.

RESULTS AND DISCUSSION

Student Performance Across Four Numeracy-Based Quizzes

The mean scores were 8.34, 8.72, 8.66, and 8.91 for Quizzes 1–4, respectively. The pattern shows an overall increase of 0.57 points from the first to the fourth quiz, with a small decline of 0.06 points between Quizzes 2 and 3. Thus, the evidence is best described as a generally upward performance trend rather than a strictly monotonic increase.

Table 2. Mean Scores Across the Four Contextual Problem-Solving Quizzes

Quiz	Context	Mean score
Quiz 1	Wet bread and dry bread	8.34
Quiz 2	Fertilizer I and Fertilizer II	8.72
Quiz 3	Men’s and women’s shoes	8.66
Quiz 4	Liquid and granular fertilizers	8.91

Interview evidence helped explain the temporary decrease in Quiz 3. Two students did not use a ruler when drawing the feasible region, which reduced graphical accuracy. This observation is pedagogically relevant because linear programming requires coordination between algebraic constraints and graphical representation. Difficulties in translating among verbal, symbolic, tabular, and graphical forms are well

documented in mathematics learning (Ainsworth, 2006; Rau, 2017; Ott et al., 2018; Duval, 2006). The result suggests that numeracy assessment should attend not only to calculation but also to representational precision and interpretation.

Evidence of the Four Problem-Solving Stages

Selected student work indicated evidence of all four problem-solving stages. In Quiz 1, a student identified the objective and constraints, connected them to the defining features of linear programming, and justified the classification of the situation. In Quiz 2, a student defined variables, organized resource restrictions, and formulated a system of linear inequalities. In Quizzes 3 and 4, students constructed feasible regions and used them to reason about maximum profit or minimum cost. These behaviors align with research describing successful mathematical problem solving as coordinated work across comprehension, representation, strategy, execution, and verification (Schoenfeld, 2016; Rott, 2020; Verschaffel et al., 2020; Schukajlow et al., 2018).

Formative Value of Repeated Contextual Quizzes

The repeated quiz format created several occasions for students to retrieve prior knowledge and apply it to new contexts. Such spacing and retrieval opportunities can strengthen access to learned procedures and concepts, while constructed responses make students' reasoning visible (Roediger & Karpicke, 2006; Rowland, 2014; Adesope et al., 2017; Yang et al., 2021). The quizzes also provided the teacher with evidence for follow-up explanation, including correction of inaccurate feasible-region drawings. This use of assessment evidence is consistent with formative-assessment principles emphasizing feedback loops and instructional adjustment (Black & Wiliam, 2009; Bennett, 2011; Wiliam, 2011; Schildkamp et al., 2020).

Limitations

Three limitations constrain interpretation. First, the study involved one purposively selected class of 36 students, so findings cannot be generalized statistically. Second, there was no control group or baseline measure; consequently, the increase from Quiz 1 to Quiz 4 cannot be attributed solely to the quiz strategy because task difficulty, ongoing instruction, and growing familiarity with linear programming may also have contributed. Third, the four quizzes differed in contextual content and mathematical demands. Future studies should use larger samples, common or equated measures, explicit inter-rater procedures, and quasi-experimental or mixed-method designs to estimate learning effects more rigorously.

CONCLUSION AND RECOMMENDATIONS

The four numeracy-based contextual quizzes produced mean scores of 8.34, 8.72, 8.66, and 8.91. The overall pattern indicates higher performance at the end of the sequence than at the beginning, although Quiz 3 showed a slight decline. Students' written work and interviews demonstrated the four targeted problem-solving processes: understanding the problem, planning a solution, carrying out the plan, and checking the result. Numeracy-based contextual quizzes can therefore serve as a practical formative assessment for linear programming because they require students to connect real situations with mathematical models and justify decisions. Teachers are encouraged to provide explicit feedback on representations, especially feasible-region construction, and to use quiz evidence to plan subsequent instruction. Stronger research designs are recommended before making causal claims about effectiveness.

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