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Writing-to-Learn with Self-Regulation Prompts for Deeper Conceptual Understanding and Higher-Order Skill Development: Implementation, Student Response, and Lessons Learned

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Writing-to-Learn with Self-Regulation Prompts for Deeper Conceptual Understanding and Higher-Order Skill Development: Implementation, Student Response, and Lessons Learned from an NSF HBCU-EiR Project

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Abstract

Writing-to-Learn (WTL) strategies are widely promoted to support conceptual understanding and self-regulated learning in engineering education, yet classroom-scale evidence remains mixed. This study examines the implementation of a WTL framework with embedded self-regulation prompts in a core undergraduate engineering course across three instructional cycles. The intervention integrated problem rationales, structured learning plans, self-evaluations, and reflective writing within regular coursework, and student responses were evaluated using analytic rubrics aligned with cognitive, metacognitive, and motivational dimensions. Descriptive analyses revealed modest and uneven outcomes. While aggregate performance gains were inconsistent, rubric-level patterns suggested meaningful variation in students' written reasoning and self-regulatory engagement across cycles. Participation in reflective components declined over time, highlighting sustainability challenges. Rather than advancing strong causal claims, this study contributes implementation-level evidence and practical design insights for integrating WTL with self-regulation prompts in engineering courses.

1 Introduction

Engineering education has traditionally emphasized procedural problem solving and algorithmic proficiency, often assessed through homework and timed examinations. While effective for evaluating computational accuracy, such approaches may not fully capture students' conceptual understanding or ability to regulate their own learning [1, 2]. Writing-to-Learn (WTL) strategies have been proposed as a means to make student thinking visible by requiring learners to articulate reasoning and justify decisions [3, 4]. When combined with prompts that target self-regulated learning (SRL), including planning, monitoring, and evaluation, writing activities may support deeper engagement and metacognitive development [5, 6].

Prior research suggests that writing and metacognitive prompts can enhance learning in STEM contexts, though outcomes vary across instructional settings [7, 8]. In engineering education specifically, fewer studies document how integrated WTL and SRL approaches function when implemented iteratively within required courses that face practical constraints such as workload, participation variability, and grading demands [9, 10].

This study reports the classroom implementation of a WTL framework with embedded self-

regulation prompts across three instructional cycles in a foundational engineering course. The framework incorporated five recurring components: written rationales for problem solving, structured learning plans, quiz rationales with feedback, self-evaluations of performance, and reflective writing. Using rubric-based analysis and exploratory trend examination, we analyze student response patterns, metacognitive calibration, and associations between early planning behaviors and later performance. Rather than advancing causal claims about learning gains, this paper focuses on implementation outcomes, student engagement patterns, and lessons learned that may inform the design and refinement of WTL activities in engineering education.

2 Methods

The study was conducted in a required undergraduate engineering course at a large public institution. A total of 85 students were enrolled in the course and were assigned Writing-to-Learn (WTL) activities as part of regular coursework. Participation contributed to bonus course credit, resulting in variation in submission rates across activities and instructional cycles.

The instructional design was informed by a self-regulated learning (SRL) framework emphasizing cognitive, metacognitive, and motivational dimensions of learning. Across three instructional cycles during the semester, five recurring WTL components were implemented: (1) written rationales for practice problems, (2) structured learning plans completed prior to quizzes, (3) quiz problem rationales with feedback, (4) post-quiz self-evaluations, and (5) reflective writing focused on learning processes and adjustments. Each component was designed to elicit conceptual reasoning, planning, monitoring, and motivational regulation.

Student writing artifacts were evaluated using analytic rubrics aligned with the intended purpose of each activity. Problem rationales emphasized conceptual identification, explanation of relationships, and justification of solutions. Learning plans were scored for clarity of goals, identification of anticipated challenges, and articulation of cognitive and metacognitive strategies. Self-evaluations and reflections were scored for evidence of monitoring, identification of strengths and weaknesses, and proposed adjustments to learning strategies. Rubric scores represent observable indicators of self-regulated learning processes as articulated in writing rather than direct measures of internal psychological states. Rubrics were applied consistently across instructional cycles.

Data analysis was descriptive and exploratory, consistent with the study's focus on instructional implementation. Summary statistics were calculated for rubric-based writing scores across instructional cycles, and visualizations were used to examine patterns in student responses over time. Relationships between selected writing components and quiz performance were explored to examine alignment between articulated self-regulatory processes and demonstrated outcomes. The analyses were not designed to establish causal claims, but rather to characterize implementation patterns and student response trends within an authentic classroom context.

3 Results

This section reports descriptive findings from the implementation of the Writing-to-Learn (WTL) framework across three instructional cycles. Analyses focus on participation patterns, rubric-based performance trends, and exploratory relationships between self-regulatory writing and quiz

outcomes.

Table 1: Participation rates across WTL components and cycles

Component	**Cycle 1** (%)	**Cycle 2** (%)	**Cycle 3** (%)
Practice Problems	94.12	85.88	83.53
Learning Plan	61.18	-	-
Quiz Problems	85.88	91.76	88.24
Self-Evaluation	62.35	52.94	50.59
Self-Reflection	60.00	44.71	50.59

Participation varied across WTL components and cycles (Table 1). Practice and quiz problems showed consistently high participation due to their alignment with course assessment, whereas learning plans and reflective writing activities showed lower and declining submission rates after Cycle 1. Analyses use all available data for each component.

Table 2: Mean (SD) rubric scores for practice and quiz problems by cycle

Cycle	**Practice Problems**	**Quiz Problems**
1	77.74 (16.26), $N = 80$	78.27 (19.64), $N = 73$
2	62.99 (31.10), $N = 73$	61.97 (27.15), $N = 78$
3	53.71 (32.35), $N = 71$	74.71 (19.37), $N = 75$

Note: N varies across cells due to unequal participation across cycles and assessment components.

Table 2 summarizes mean rubric scores for practice and quiz problems across cycles. In Cycle 1, practice and quiz performance were comparable. In Cycle 2, both declined. In Cycle 3, quiz scores exceeded practice scores by a substantial margin. Thus, performance patterns varied across cycles rather than demonstrating a uniform trend, with the strongest post-practice improvement observed in Cycle 3.

Table 3: Descriptive statistics for Cycle 1 learning plan rubric dimensions ($N = 52$)

Rubric Dimension	**Mean (SD)**
Motivational Perspective (30%)	19.31 (4.49)
Cognitive Perspective (40%)	28.12 (5.97)
Metacognitive Perspective (30%)	17.33 (6.71)

Learning plan quality (Cycle 1; $N = 52$) showed higher mean scores for the cognitive dimension relative to motivational and metacognitive dimensions (Table 3), suggesting that students more readily articulated content-focused preparation strategies than monitoring or adaptation plans.

Table 4 lists mean rubric scores for self-evaluation and self-reflection across the three instructional cycles, using all available submissions in each cycle. The scores for both activities increased from Cycle 1 to Cycle 2, though participation declined in later cycles. To examine alignment between perceived understanding and performance, self-evaluation scores were compared with corresponding quiz scores (Fig. 1). While higher quiz performance was often accompanied by higher self-evaluation scores, substantial dispersion and instances of miscalibration were observed

Table 4: Mean self-evaluation and self-reflection scores across instructional cycles

Cycle	Self-evaluation	Self-reflection
1	68.45	65.73
2	71.11	70.63
3	70.23	64.02

across cycles. These patterns suggest variability in students' self-assessment accuracy despite repeated exposure to reflective activities.

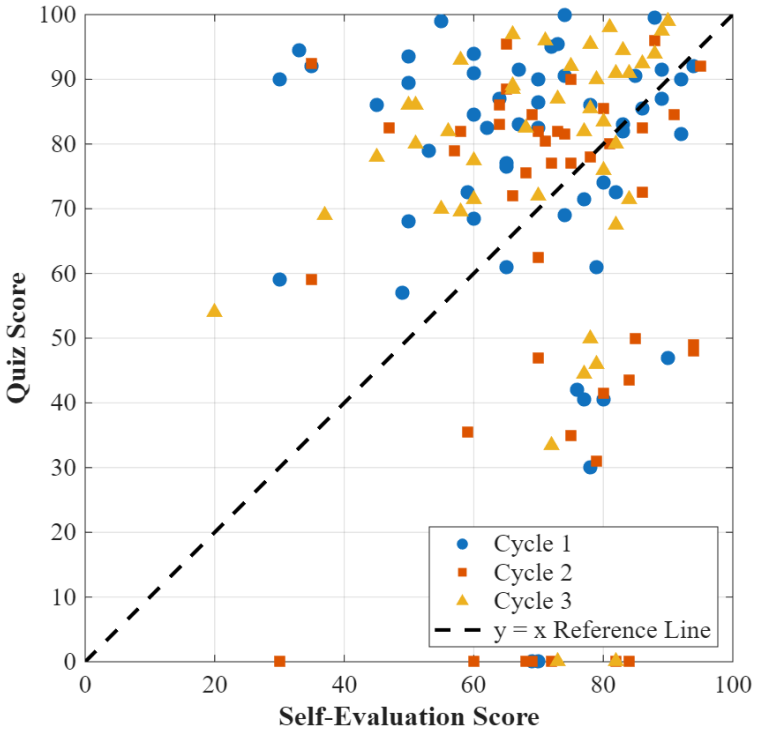

Figure 1: Paired self-evaluation and quiz scores across instructional cycles. The dashed line represents equal self-evaluation and quiz scores. Sample sizes vary by cycle due to declining participation.

Overall, the findings indicate that implementation of the WTL framework elicited measurable engagement across cognitive, metacognitive, and motivational dimensions, although participation and performance patterns varied across activities and cycles.

4 Discussion

This section interprets the findings in light of prior Writing-to-Learn (WTL) and metacognition research, with attention to the practical constraints of undergraduate engineering instruction. Results revealed modest and uneven patterns across performance, metacognitive engagement, and participation rather than uniform gains.

Although aggregate quiz improvements were inconsistent, dimension-level patterns suggested

stronger performance in higher-order reasoning categories (application, evaluation, synthesis) relative to foundational concept identification. This aligns with prior WTL research indicating that writing may preferentially support deeper conceptual processing rather than surface recall. In engineering contexts, where procedural success can mask conceptual gaps, such shifts toward higher-order reasoning are educationally meaningful even in the absence of large overall score gains.

Self-evaluation analyses revealed substantial variability in calibration between perceived and demonstrated understanding. Some lower-performing students rated their understanding highly, particularly in early cycles. This pattern is broadly consistent with metacognitive calibration challenges described in the Dunning-Kruger literature [11], although the present study was not designed to test that effect directly. While modest improvement in calibration was observed in later cycles, misalignment persisted for some students, indicating that accurate self-assessment likely requires sustained and explicit instructional support.

Declining participation across cycles highlights an important implementation challenge. Reflective and planning activities were completed less consistently than assessment-aligned problem-solving tasks, suggesting that sustainability depends on careful integration with course grading structures and workload expectations.

Several lessons emerged from this implementation. First, prompts emphasizing justification and evaluation may be promising for promoting higher-order reasoning in engineering courses. Second, metacognitive calibration develops incrementally and may require longer-term integration than a single semester cycle. Third, participation burden must be considered when embedding reflective writing in technically intensive courses.

Rather than advancing strong causal claims, this study contributes implementation-level evidence regarding how WTL with self-regulation prompts functions in authentic engineering classrooms. By documenting both variability and constraint, the findings inform future refinement of reflective and self-regulatory supports in engineering education.

5 Conclusion

This study examined the implementation of a Writing-to-Learn (WTL) framework with embedded self-regulation prompts across three instructional cycles in an undergraduate engineering course. The intervention integrated problem rationales, learning plans, quizzes with feedback, self-evaluations, and reflective writing to support conceptual reasoning and metacognitive engagement.

Results revealed modest and uneven patterns. Aggregate quiz performance did not consistently improve across cycles, and participation in reflective components declined over time. Among available submissions, self-evaluation and self-reflection scores showed modest variation across cycles, but unequal participation limits strong longitudinal interpretation. The comparison between self-evaluation and quiz performance also showed substantial dispersion, suggesting persistent variability in students' metacognitive calibration.

Overall, the findings suggest that WTL with self-regulation prompts can provide useful opportunities for students to articulate reasoning, monitor performance, and reflect on learning

strategies. However, the impact of these activities depends on sustained participation, thoughtful workload design, and explicit instructional support. Future work should refine integration strategies, add stronger longitudinal analyses, and examine longer-term effects on learning and self-regulation.

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