

## The Impact of Supporting Productive Struggle in Learning Mathematics: A Quasi-Experimental Study in High School Algebra Classes

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**Abstract :** Productive struggle entails a student's cognitive exertion to comprehend mathematical concepts and uncover solutions not immediately apparent. The significance of productive struggle in learning mathematics is accentuated by influential educational theorists, emphasizing its necessity for learning mathematics with understanding. Consequently, supporting productive struggle in learning mathematics is recognized as a high-leverage and effective mathematics teaching practice. In this study, the investigation into the role of productive struggle in learning mathematics led to the development of a comprehensive rubric for productive struggle pedagogy through an exhaustive literature review. The rubric consists of eight primary criteria and 37 sub-criteria, providing a detailed description of teacher actions and pedagogical choices that foster students' productive struggles. These criteria encompass various pedagogical aspects, including task design, tool implementation, allowing time for struggle, posing questions, scaffolding, handling mistakes, acknowledging efforts, and facilitating discussion/feedback. Utilizing this rubric, a team of researchers and teachers designed eight 90-minute lesson plans, employing a productive struggle pedagogy, for a two-week unit on solving systems of linear equations. Simultaneously, another set of eight lesson plans on the same topic, featuring identical content and problems but employing a traditional lecture-and-practice model, was designed by the same team. The objective was to assess the impact of supporting productive struggle on students' mathematics learning, defined by the strands of mathematical proficiency. This quasi-experimental study compares the control group, which received traditional lecture- and practice instruction, with the treatment group, which experienced a productive struggle in pedagogy. Sixty-six 10th and 11th-grade students from two algebra classes, taught by the same teacher at a high school, underwent either the productive struggle pedagogy or lecture-and-practice approach over two-week eight 90-minute class sessions. To measure students' learning, an assessment was created and validated by a team of researchers and teachers. It comprised seven open-response problems assessing the strands of mathematical proficiency: procedural and conceptual understanding, strategic competence, and adaptive reasoning on the topic. The test was administered at the beginning and end of the two weeks as pre-and post-test. Students' solutions underwent scoring using an established rubric, subjected to expert validation and an inter-rater reliability process involving multiple criteria for each problem based on their steps and procedures. An analysis of covariance (ANCOVA) was conducted to examine the differences between the control group, which received traditional pedagogy, and the treatment group, exposed to the productive struggle pedagogy, on the post-test scores while controlling for the pre-test. The results indicated a significant effect of treatment on post-test scores for procedural understanding ( $F(2, 63) = 10.47, p < .001$ ), strategic competence ( $F(2, 63) = 9.92, p < .001$ ), adaptive reasoning ( $F(2, 63) = 10.69, p < .001$ ), and conceptual understanding ( $F(2, 63) = 10.06, p < .001$ ), controlling for pre-test scores. This demonstrates the positive impact of supporting productive struggle in learning mathematics. In conclusion, the results revealed the significance of the role of productive struggle in learning mathematics. The study further explored the practical application of productive struggle through the development of a comprehensive rubric describing the pedagogy of supporting productive struggle.

**Keywords :** effective mathematics teaching practice, high school algebra, learning mathematics, productive struggle

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