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BOARD # 330: Broadening Participation in STEM Through Contextualized Algebra: Promise and Challenges from an NSF ATE project

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Broadening Participation in STEM Through Contextualized Algebra: Promise and Challenges from an NSF ATE project

Introduction

The gender gap in STEM fields remains a persistent issue, with women significantly underrepresented in math-intensive disciplines despite recent progress in course-taking and performance. This imbalance arises from multiple factors, including differences in cognitive abilities, interests, lifestyle preferences, and the impact of gender-related stereotypes [1].

In the U.S., academic culture often favors "low-context" approaches, which can marginalize students who thrive in "high-context" learning environments. High-context approaches, such as communal work and contextualized learning, are generally preferred by women and minority students. These methods have the potential to broaden academic culture and foster more inclusive environments [2].

Research in both secondary and postsecondary education suggests that women are more likely than men to engage with STEM topics when they are linked to societal, interpersonal, or practical applications, such as health and environmental sciences [3, 4]. Curricula and teaching strategies that emphasize hands-on, collaborative learning and real-life relevance have been shown to effectively foster interest and engagement, particularly among female students [1, 3, 4].

Civic engagement pedagogies offer a promising pathway for increasing women's representation in STEM. These approaches not only enhance diversity but also lead to more innovative ideas and initiatives [5]. Furthermore, active learning methods have been demonstrated to reduce motivational disparities between men and women in introductory STEM courses, resulting in more equitable motivational profiles that support learning engagement, persistence, and achievement [6].

These strategies underscore the importance of incorporating gender considerations into STEM education. However, it is critical to recognize that gender is just one of several intersecting factors, including race, ethnicity, and socioeconomic status. By adopting inclusive teaching practices and offering diverse course content, educators can make meaningful strides toward closing the gender gap in STEM fields [4].

To explore these issues, this study investigates the impact of contextualized algebra modules on student performance, engagement, and attitudes toward STEM in a community college setting. Specifically, we ask: How does a contextualized algebra curriculum influence student performance, engagement, and attitudes toward STEM, particularly for women and students with varying levels of prior academic achievement?

Methods

Six algebra modules were developed to incorporate real-world applications from fields such as physics, engineering, environmental science, and healthcare. These modules were designed to enhance the relevance of algebra by embedding altruistic and practical STEM contexts,

particularly to engage women and underrepresented students in STEM. The modules were implemented across twelve course sections over four semesters, from Fall 2021 to Spring 2023 taught by the same instructor who developed the modules.

Student performance data, including course grades and cumulative GPA, were collected from institutional records. A total of 690 students who enrolled in the course had both GPA and course grades on record and were included in the analysis, of which 114 were from contextualized sections.

Student attitudes toward mathematics and STEM were assessed using matched pre- and post-semester surveys. These surveys included demographic questions as well as items designed to measure changes in attitudes toward mathematics and STEM. Each student's pre-survey responses were paired with their corresponding post-survey responses, allowing for direct measurement of changes over the semester. Students rated their agreement with the following statements on a Likert scale:

- I enjoy doing math.
- Math word problems fascinate me.
- Math classes provide the opportunity to gain knowledge that is useful in real life.
- I would consider college majors in science, technology, engineering or math.
- I would consider a career in science, technology, engineering or math.

The first three statements were added in the second year of the study to capture broader attitudinal shifts. A total of 288 students completed both pre- and post-surveys, including 77 from contextualized sections and 211 from non-contextualized sections. To avoid response bias, we assessed the impact of contextualized algebra modules indirectly through general survey questions on mathematics and STEM attitudes, rather than asking students explicitly about the curriculum.

We used linear and segmented regression to analyze the relationship between GPA and course grades, identifying key GPA breakpoints. This approach assessed whether contextualized modules influenced the predictive strength of GPA on course performance while normalizing outcomes across student backgrounds.

Descriptive statistics and paired t-tests were used to analyze changes in survey responses, leveraging the matched pre- and post-survey data for each student. This within-subject design provided a more robust measure of change by controlling individual baseline attitudes. The analysis stratified responses by section type (contextualized vs. non-contextualized) and gender to examine whether the contextualized modules had differential effects on attitudes toward STEM for men and women.

Results

Figure 1 illustrates the relationship between course grades and GPA for students enrolled in all Intermediate Algebra sections over four semesters. A simple linear regression model identified a statistically significant relationship between GPA and course grades ($F(1,788)=84.30$, $p < 0.001$) with a coefficient of determination of $R^2 = 0.097$. This indicates that GPA accounts for only 9.7% of the variability in course grades, suggesting a modest predictive relationship.

Upon closer examination of the scatter plot, distinct trends emerged for students with low and high GPAs, prompting further investigation through segmented regression to better capture these differences and potentially improve the R^2 value. A MATLAB routine was implemented to fit a two-segment regression model, iterating GPA breakpoints in increments of 0.1 across the observed range of GPA values. The optimal breakpoint was identified at GPA=2.9, minimizing the sum of squares error.

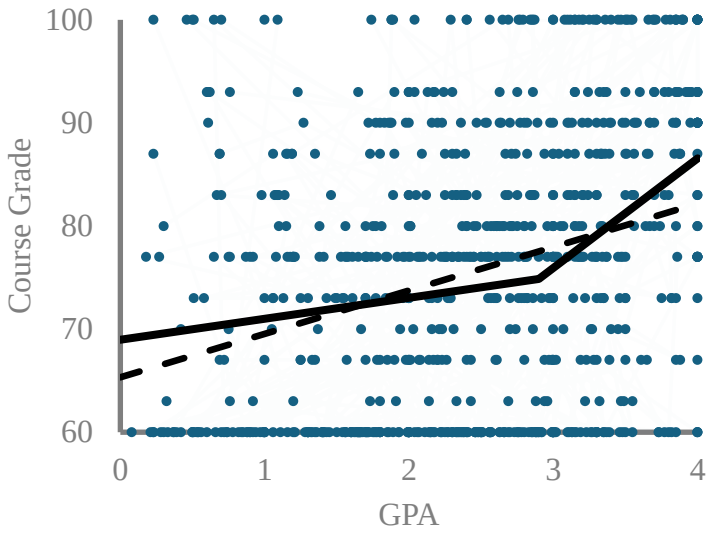

Figure 1 - Students Course Grade plotted against their GPA at the start of the semester. The dashed and solid lines show simple and segmented regression respectively.

The segmented regression analysis revealed two distinct trends. For students with GPAs below the breakpoint (GPA<2.9) the slope of the regression line was 0.23 (95% CI: 0.08 to 0.36), indicating a weak, statistically significant positive relationship between GPA and course grades. Conversely, for students with GPAs above the breakpoint (GPA≥2.9), the slope increased substantially to 10.63 (95% CI: 7.61 to 13.65), reflecting a much stronger and statistically significant positive relationship.

A t-test confirmed that the difference between the two slopes was statistically significant ($t(399)=6.18$, $p<0.001$) supporting the appropriateness of segmented regression over a simple linear regression. The segmented regression model achieved a higher coefficient of determination (R^2 = 0.118), indicating an improved ability to capture the variability in course grades compared to the single regression model.

Student data were categorized into four groups based on gender and enrollment in contextualized or non-contextualized sections. A segmented regression model was applied to each group, using the same GPA breakpoint of 2.9 identified in the overall analysis. The segmented regression results

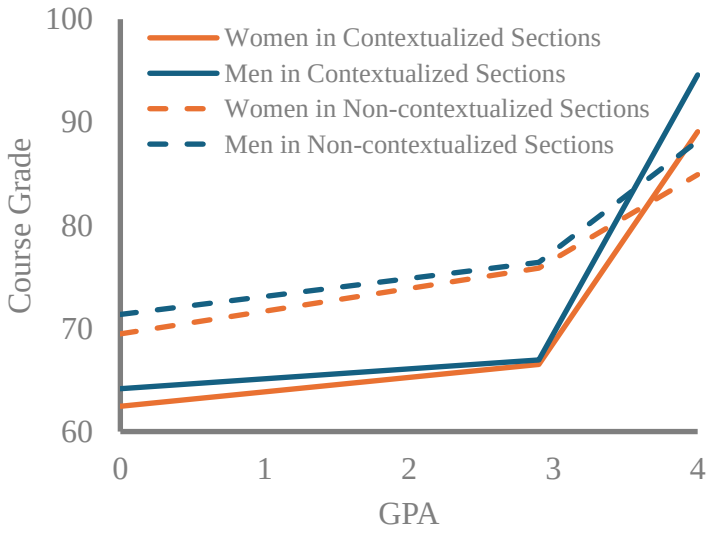

Figure 2 - Segmented regression for Course Grade vs GPA data for each category of Gender x Contextualized Section enrollment.

are visualized in Figure 2, and detailed regression model parameters and associated statistics are reported in Table 1.

The segmented regression analysis revealed significant differences in the slopes for low GPA and high GPA segments across all four groups. For both contextualized and non-contextualized sections, the high GPA slopes were substantially steeper than the low GPA slopes, indicating a stronger positive relationship between GPA and course grades for students with higher GPAs. The significant difference in these slopes underscores the need to account for GPA segmentation when analyzing the relationship between GPA and course grades.

Table 1 - Results of segmented regression analysis for men and women who enrolled in contextualized or non-contextualized sections separately

				Low GPA Segment		High GPA Segment	
Section	Gender	F-statistics	R^2	Slope (95% CI)	Intercept (95% CI)	Slope (95% CI)	Intercept (95% CI)
Context.	Women	F(2,62) = 16.5 P<0.0001	0.347	1.4 (-2.1 to 4.9)	62.4 (55.2 to 69.7)	20.5 (11.5 to 29.5)	15.86 (7.0 to 24.7)
	Men	F(2,46) = 13.5 P<0.0001	0.369	0.9 (-3.5 to 5.4)	64.2 (54.9 to 73.4)	25.1 (13.1 to 37.2)	11.9 (1.9 to 21.8)
Non-context.	Women	F(2,406) = 21.6 P<0.0001	0.096	2.2 (0.3 to 4.1)	69.5 (65.1 to 73.8)	8.24 (4.4 to12.1)	50.71 (46.4 to 55.0)
	Men	F(2,264) = 13.6 P<0.0001	0.093	1.74 (-0.6 to 4.0)	71.4 (66.6 to 76.1)	10.7 (4.7 to 16.7)	48.2 (42.6 to 53.8)

In the low GPA segment, three out of four groups had slopes not significantly different from zero, indicating a weak relationship between GPA and course performance. This suggests GPA was not a strong predictor of success for these students. Contextualized sections had slightly lower intercepts than non-contextualized ones, but these differences were not statistically significant, making it unclear whether contextualization affected baseline performance.

In the high GPA segment, contextualized sections exhibited steeper slopes than non-contextualized sections, indicating a stronger GPA-course grade relationship. While not statistically significant, this suggests a potential performance benefit for high-achieving students. Gender comparisons revealed similar trends, with both men and women

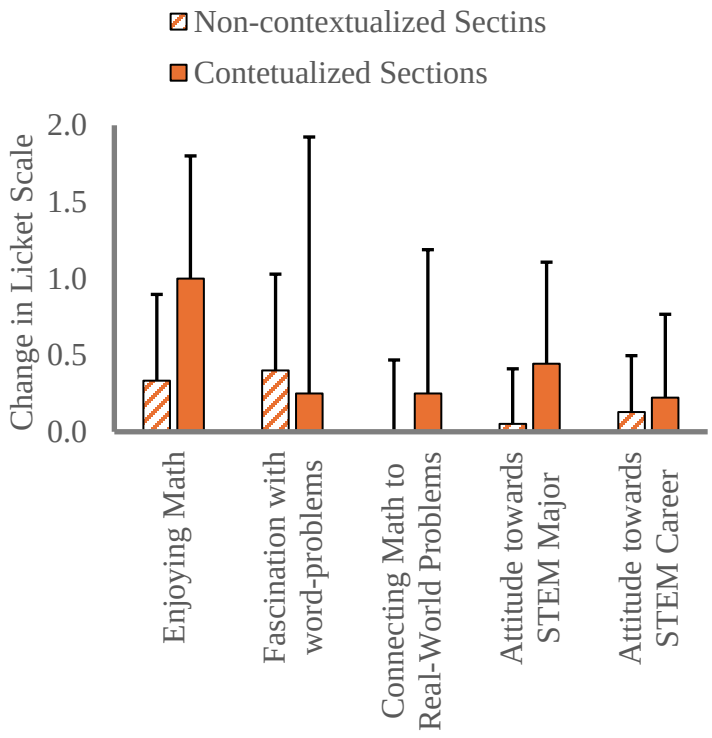

Figure 3 - Change in women's attitude in high GPA segment towards math and STEM from pre- and post-surveys for contextulized and non-contextualized sections. The error bars show +95% confidence intervals.

in contextualized sections showing steeper slopes than their non-contextualized counterparts, though men's slopes were slightly steeper, hinting at potential gender-based differences.

The survey results for students in the high GPA segment followed a different pattern compared to those in the low GPA segment, where contextualized sections showed a contradictory and sometimes negative effect on students' attitudes (not shown here). Figure 3 displays the changes in responses from women in the high GPA segment to survey questions about their attitudes toward mathematics and STEM, comparing contextualized and non-contextualized sections. None of the observed differences between the two groups reached statistical significance.

While the differences were not significant, women in the high GPA segment generally exhibited positive trends which was more prominent for contextualized sections. These students showed greater improvements in their enjoyment of math, and ability to connect math to real-world problems compared to their peers in non-contextualized sections. Similarly, their attitudes toward pursuing STEM majors and careers also demonstrated modest positive shifts.

Discussion

This study examined the effects of contextualized algebra modules on student performance and attitudes toward STEM in a community college setting. The findings suggest that the impact of contextualized learning varies significantly across students with different academic abilities and highlights the importance of tailoring instructional approaches to meet diverse needs [1].

Contextualized sections showed a stronger GPA-course grade relationship for high-GPA students, suggesting benefits for those with strong academic foundations. Women in this group displayed modest positive attitudinal shifts, though not statistically significant. In contrast, low-GPA students did not experience grade improvements, and in some cases, attitudes toward STEM declined. These findings highlight the need for additional support strategies to help lower-achieving students fully benefit from contextualized learning.

Variability in student outcomes highlights the complexity of implementing contextualized curricula, aligning with prior research [7]. While promising for high-performing students, its impact on lower-GPA students remains uncertain, warranting further research into differentiated instruction and support systems.

Beyond contextualized instruction, factors such as teaching style, grading practices, and student demographics may have influenced outcomes. Future research should examine how instructional methods and assessment alignment impact student performance. Additionally, qualitative analysis—using student reflections or automated sentiment analysis—could provide deeper insights into engagement with contextualized learning.

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