

Comparing Traditional and Modern Teaching Methods in Mathematics Education: Effects on Undergraduate Students' Achievement and Motivation

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ABSTRACT. This study explored the influence of teaching methodology and education level on college students' mathematical achievement and motivation. We predicted the scores on respective measures to be higher for students in the modern teaching method as compared to the traditional teaching method, and that scores would increase with the level of mathematics education. Forty-three undergraduate students from a private liberal arts college participated in the experiment. A pretest-posttest design was used to examine mathematical achievement; the Mathematics Motivation Questionnaire was administered following the intervention to measure motivation. Interestingly, teaching method had little to no effect on student achievement, $F(1, 37) = 2.00, p = .17$, partial $\eta^2 = .05$, and motivation, Wilks' Lambda = .86, $F(1, 41) = 1.25, p = .30$, though the advanced and intermediate students scored significantly higher on the posttest, $F(2, 37) = 3.96, p = .03$, partial $\eta^2 = .18$, and the motivation subscores of self-regulation, self-efficacy, and utility value, Wilks' Lambda = .59, $F(2, 40) = 2.16, p = .03$, than the introductory students. Implications include instruction oriented toward motivating students on their mathematical abilities, encouraging connection and recall to previously learned concepts, and continued assessment of long-term influences of teaching methodology on success outcomes.

Keywords: mathematics education, teaching methods, college students, achievement, motivation

The effectiveness of teaching methods in education has long been a subject of inquiry, with educators continually exploring ways to enhance instructional efficiency and effectiveness. In mathematics education, the conventional approach often involves introducing topics with concrete examples and gradually progressing toward more abstract concepts as students develop their understanding through practice (McNeil et al., 2019). These teaching methods, whether traditional or modern, play a pivotal role in shaping the learning experience.

Traditional teaching methods are teacher-centered, emphasizing lectures and textbook-driven memorization through repetition and practice problems (Demirel, 2012, as cited in San & Kis, 2018; Hidalgo-Cabrillana & Mayan-Lopez, 2018; Tularam & Machisella, 2018). This approach relies on clear explanations, demonstrations, and guidance from the instructor to achieve skill mastery (Noreen & Rana, 2019; Umugiraneza et al., 2017;

Voskoglou, 2019). In contrast, modern teaching methods prioritize student engagement and comprehension through activities that foster critical thinking, problem-solving, and collaborative learning (Noreen & Rana, 2019; Tularam & Machisella, 2018). These methods promote active participation, discussion, and the development of higher-order thinking skills (Bonwell, 1991, as cited in Roop et al., 2018; Hidalgo-Cabrillana & Mayan-Lopez, 2018).

The preference of teaching method varies with the students' education level. Modern teaching methods tend to yield significant results in primary education by promoting deep conceptual understanding (Hidalgo-Cabrillana & Mayan-Lopez, 2018; McNeil et al., 2019) and demonstrate improved performance in secondary education (Akcakin, 2017; Damrongpanit, 2019; Noreen & Rana, 2019; Umugiraneza, 2017). However, instructors may default to using traditional approaches when faced with unfamiliar material, exacerbated even more when they know only a handful of alternative methods for

instruction and assessment (Umugiraneza et al., 2019). Conversely, traditional methods may be favored due to their relative simplicity and frequency of usage as a tried-and-true method (San & Kis, 2018). In postsecondary education, students often express a preference for modern methods when given a choice (Roop et al., 2018; Voskoglou, 2019). These methods adapt content to the developmental stage of students, addressing foundational concepts in lower-level courses and more complex ideas in upper-level courses, often yielding outcomes that match or exceed traditional approaches.

Mathematical achievement is commonly measured by assessing a student's mastery of mathematical concepts through problem-solving and performance on tests (McNeil et al., 2019; Noreen & Rana, 2019). This achievement can also involve setting goals, both external (e.g., awards and competitions) and internal (e.g., self-satisfaction; Akcakin, 2017). Some studies additionally break down mathematical achievement into components such as mathematical self-efficacy, achievement motivation, and attitude, which collectively influence overall achievement (see Damrongpanit, 2019). *Mathematical motivation* reflects a student's interest and desire to understand mathematical concepts (Damrongpanit, 2019). It encompasses intrinsic value, self-regulation, self-efficacy, utility value, and test anxiety (Fiorella et al., 2021). Motivation can also be assessed based on learning strategies, perceived value of learning, goal orientation, and the learning environment (Akcakin, 2017).

Roop et al. (2018) and Voskoglou (2019) previously investigated the two instructional methods on collegiate populations with results favoring the modern methods in terms of producing higher rates of achievement and preference, paralleling those conducted on primary and secondary school populations (Hidalgo-Cabrillana & Mayan-Lopez, 2018; McNeil et al., 2019; Noreen & Rana, 2019); however, both studies targeted a single, introductory-level course rather than surveying a more general student population. Mathematical motivation has been studied less frequently with this population, presenting a relative gap in the literature, especially when surveying students with various levels of mathematical backgrounds and experiences.

In the current study, we assessed the impact of both traditional and modern teaching methods on college students across various levels of math education. In alignment with prior findings, students who were exposed to modern teaching methods were expected to demonstrate higher scores in both achievement and motivation when compared to their counterparts in the traditional teaching group; similarly, we expected that students with advanced mathematical experience would outperform those at intermediate and introductory levels.

Method

Participants

Forty-three undergraduate students were recruited through convenience sampling from a small private liberal arts college in Arkansas: participants ranged

TABLE 1

Participant Demographic Characteristics by Condition and Education Level

Characteristic	Teaching Condition		Mathematics Education Level			Total
	Traditional	Modern	Introductory	Intermediate	Advanced	
Gender						
Men	13	17	13	7	10	30
Women	9	4	7	4	2	13
Race/Ethnicity						
African American	0	6	5	0	1	6
Asian	0	1	0	0	1	1
Asian American/ Pacific Islander	3	1	0	1	3	4
European American	15	10	10	9	6	25
Hispanic/Latin American	0	2	2	0	0	2
Multiracial	2	1	2	1	0	3
Other/Not Specified	2	0	1	0	1	2
Total	22	21	20	11	12	43

Note. Chi-squared tests were run to evaluate the similarity of groups based on the demographic variables recorded. The only pairing that showed significant difference was between race/ethnicity and teaching condition, $\chi^2(7) = 16.00, p = .03$, Cramer's $V = .61$, which is most likely due to the demographics of the population the sample was pulled from.

TABLE 2

Pretest and Posttest Exercises With Overall Average Scores

Exercise	M	SD
Pretest		
Evaluate 8^4 .	4.14	1.46
If you have 10 trophies, how many ways are there to arrange 8 of them on a shelf?	1.72	1.40
There are 13 jellybeans in a jar. How many ways are there to choose 4 of them if order does not matter?	1.65	1.45
Posttest		
Evaluate ${}_8C_3$.	3.91	1.66
How many total outfits can you create with 5 shirts, 4 pants, 8 pairs of socks, and 5 pairs of shoes?	4.70	1.01
How many unique ways are there to rearrange the letters in "NEW YORK"?	3.77	1.62
5 people are selected from a class made up of 7 juniors and 8 seniors to represent the college population in a study. How many ways are there to select 2 juniors and 3 seniors from the class?	2.54	1.45
Evaluate ${}_7P_3$.	3.63	1.96
How many possible 10-digit phone numbers are there: (XXX) XXX-XXXX?	3.58	1.68

Note. $N = 43$.

in age from 18–24 ($M = 19.95$, $SD = 1.57$); identified as women ($n = 13$) or men ($n = 30$); were African American ($n = 6$), Asian ($n = 1$), Asian American and/or Pacific Islander ($n = 4$), European American ($n = 25$), Hispanic and/or Latin American ($n = 2$), multiracial ($n = 3$), or other/not specified ($n = 2$); and were classified as either a first-year student ($n = 17$), sophomore ($n = 11$), junior ($n = 6$), or senior ($n = 9$). Participants were recruited from a variety of mathematics courses offered during the spring semester, as well as two introductory psychology courses. Based on their highest mathematics course previously or currently enrolled in, participants were characterized as either introductory ($n = 20$), intermediate ($n = 11$), or advanced ($n = 12$) regarding their mathematics education level (all psychology students recruited met the previously or currently enrolled criteria). Participation was incentivized through the awarding of bonus points toward a concurrent mathematics class of their choosing or research experience credits as part of a course requirement for those enrolled in the introductory psychology courses.

Procedure

Approval from the Institutional Review Board for this study was completed prior to the data collection phase. Participants self-selected into one of five masked instructional sessions based on their availability when they signed up (i.e., students were unaware of which condition they were in prior to their participation). Sessions were held at 7:00 p.m. for the span of a week to meet the scheduled availability of participants. The first, third, and fifth sessions were taught using the traditional method ($n_1 = 5$, $n_3 = 8$, $n_5 = 9$; total = 22), and the second and fourth sessions were taught using the modern method ($n_2 = 7$, $n_4 = 14$; total = 21). Table 1 contains a detailed breakdown of the sample's demographics by teaching condition and mathematics education level.

Participants were given five minutes to complete a content pretest at beginning of each instructional period. Following the pretest, participants were given a blank sheet of paper and a pencil and were asked to take notes as if they were in a typical math class during the 45-minute instructional period. Once the instruction concluded, participants were given ten minutes to complete a content posttest to assess their understanding of the material covered. Following the posttest, they completed various surveys and filled out demographic information. Once they completed the surveys, the participants turned in their study materials and received a debriefing form that explained the purpose of the study and a description of the experimental conditions. A brief description of the group sessions follows.

Traditional Group

The instructor was the primary speaker during the session, using a whiteboard or similar apparatus at the front of the classroom to write notes such as definitions and examples for the students to take notes on at their own pace. The instructor introduced new concepts, worked examples at the board, and had students work exercises on their own. During examples the instructor asked students to go step by step throughout the solution process while remaining at the board to record the steps. The instructor periodically asked questions to gauge the understanding of the material among the participants and to promote engagement with the material. The session ended with a short exercise for the students to complete on their own prior to the assessment to provide them a chance to work through the solution process on their own.

Modern Group

The instructor presented the students with a short exercise to complete in randomly assigned small groups; once completed, one student from each group showed their work on the whiteboard while another explained their solution process. Students from different groups were asked to check the work on the board and ask any questions for understanding. Following this discussion, the instructor formalized the solution process using formulas and had the students take notes on how similar or different it was from their process. This was repeated for each concept covered prior to the content assessment.

Materials

The pretest and posttest assessments covering the mathematical content used questions adapted from concepts addressed within the first week of a combinatorics (advanced counting) course, an infrequently taught math course at the institution where this study was conducted. This material was recommended by mathematics faculty members based on its ease of learning across mathematical experience and its relatively low explicit instruction throughout most college-level mathematics courses. Nine questions were used; an easy, medium, and hard question was constructed for each of the three concept groups: basic counting principle, permutations, and combinations (introductory-level, intermediate-level, and advanced-level, respectively). The question order for the assessment was randomly generated with the only criteria that one easy, medium, and hard question from the subsections be selected for the pretest. All participants took the same assessment with the same question order (see Table 2).

Each content assessment question was scored using a holistic rubric from the Berkeley Graduate Division

Teaching and Resource Center (n.d.) where the content was assessed and rated for common mistakes made throughout participant data to keep scores consistent across all sessions and conditions (see Table 3). The scoring process involved three raters – the author and two volunteers – who were familiar with the assessment rubric and objectives of the study. The raters jointly reviewed each assessment and engaged in discussions to reach a consensus on the scores, with any discrepancies in ratings ultimately decided by the author.

The Mathematics Motivation Questionnaire (MMQ; Fiorella et al., 2021) was used with a 5-point Likert scale to assess participant motivation levels regarding their mathematics experience (19 items, Cronbach's $\alpha = .85$). Subscales of the questionnaire include Intrinsic Value (3 items, $\alpha = .85$), Self-Regulation (4 items, $\alpha = .73$), Self-Efficacy (4 items, $\alpha = .87$), Utility Value (4 items, $\alpha = .89$), and Test Anxiety (4 items, $\alpha = .79$). The participants' degree type (whether they were a mathematics major, minor, or neither), their prior math courses taken, and other study-specific questions were recorded but not utilized in the following analyses.

Results

The following hypotheses were tested: (a) students in the modern group would score higher on both achievement and motivation assessments as opposed to the traditional group and (b) students with higher levels of educational experience within mathematics would score higher than those with less experience. Item-wise means and standard deviations for the content assessment are presented in Table 2.

Achievement

Paired-samples t tests were conducted to assess general improvement on the content assessment from pretest to posttest for both teaching methodology and education level. Table 4 presents the means, standard deviations, and effect sizes for teaching condition, education level, and overall performance. Improvement was significant overall ($p < .001$), for teaching condition (both $ps < .001$), and across education level (all $ps \leq .01$) with large effect sizes for teaching condition and medium effect sizes for education level (see Table 4).

Mirroring the analysis of Akcakin (2017) and Voskoglou (2019), a two-way ANOVA on the pretest scores showed participants were comparable prior to the intervention (teaching method: $F(2, 37) = 0.44$, $p = .51$; education level: $F(2, 37) = 0.79$, $p = .46$; interaction: $F(2, 37) = 0.76$, $p = .47$; see Figures 1 and 2). A two-way ANOVA on the posttest scores revealed there was no significant interaction ($p = .61$) between teaching methodology and education level on the posttests scores,

TABLE 3

Content Assessment Grading Rubric

Points	If...
5	The student clearly understands how to solve the problem. Minor mistakes and careless errors can appear insofar as they do not indicate a conceptual misunderstanding.
4	The student understands the main concepts and problem-solving techniques, but has some minor yet non-trivial gaps in their reasoning.
3	The student has partially understood the problem. The student is not completely lost, but requires tutoring in some of the basic concepts. The student may have started out correctly, but gone on a tangent or not finished the problem.
2	The student has a poor understanding of the problem. The student may have gone in a not-entirely-wrong but unproductive direction, or attempted to solve the problem using pattern matching or by rote.
1	The student did not understand the problem. They may have written some appropriate formulas or diagrams, but nothing further. Or they may have done something entirely wrong.
0	The student wrote nothing or almost nothing.

TABLE 4

Means, Standard Deviations, and t Statistics for Condition and Education Level

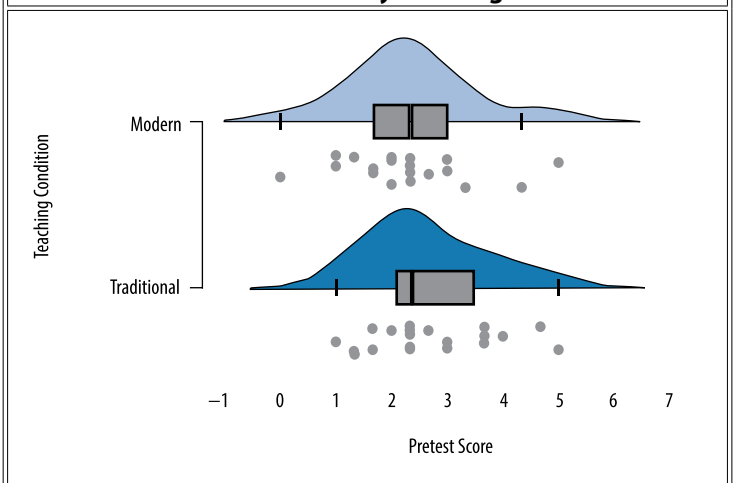
Group	Pretest		Posttest		$t(df)$	p	Cohen's d	95% CI
	M	SD	M	SD				
Overall	2.50	1.10	3.69	1.08	6.31	<.001***	0.96	[0.60, 1.32]
Traditional	2.67	1.07	3.99	1.05	4.50	<.001***	0.96	[0.44, 1.46]
Modern	2.33	1.13	3.37	1.03	4.46	<.001***	0.97	[0.44, 1.49]
Introductory	2.35	1.36	3.19	1.04	2.92	.009**	0.65	[0.16, 1.13]
Intermediate	2.39	0.76	4.17	0.74	8.40	<.001***	0.58	[1.28, 3.76]
Advanced	2.86	0.82	4.07	1.10	3.05	.01*	0.48	[0.19, 1.54]

Note. Positive scores represent improvement from pretest to posttest (paired samples t -test). The degrees of freedom (df) for each test were 42, 21, 20, 19, 10, and 11, respectively.

* $p < .05$. ** $p < .01$. *** $p < .001$.

FIGURE 1

Plot of Pretest Scores by Teaching Condition



Note. Graph generated by JASP.

TABLE 5

Descriptive Statistics for MMQ Subscales Across Education Level

Subscale	Educational Level						Cronbach's α
	Introductory	Intermediate	Advanced				
Intrinsic Value	2.35	1.36	2.39	0.76	2.86	0.82	.64
Self-Regulation	3.26	0.99	4.02	1.04	4.23	0.82	.67
Self-Efficacy	3.19	1.17	4.05	0.69	4.08	1.08	.69
Utility Value	2.86	1.16	3.82	1.06	3.96	1.02	.91
Test Anxiety	3.58	1.04	3.41	1.03	3.35	0.95	.76

Note. Total Cronbach's $\alpha = .81$.

TABLE 6

Post-Hoc Results for Significant ANOVAs of MMQ Subscales Across Education Level

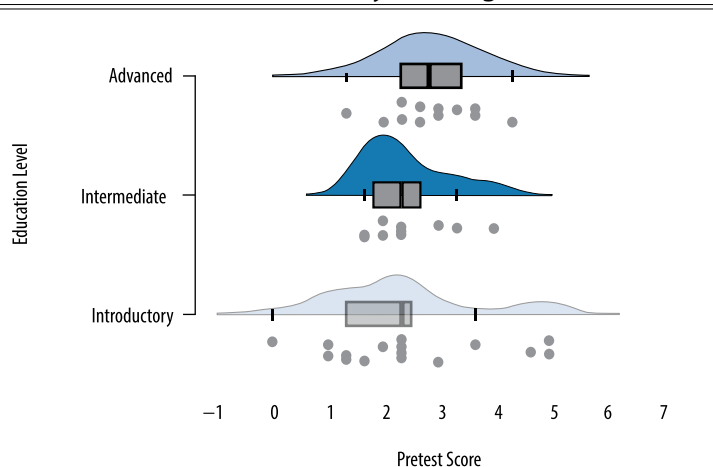
Subscale	$F(2, 40)$	p	η^2	Tukey's HSD	M_{diff}	t	p_{corr}	Cohen's d	95% CI
Self-Regulation	4.54	.02	.19	Intro vs. Inter	-0.76	-2.12	.09	-0.80	[-1.76, 0.17]
				Intro vs. Adv	-0.97	-2.77	.02*	-1.01	[-1.97, -0.06]
				Inter vs. Adv	-0.21	-0.52	.86	-0.22	[-1.26, 0.83]
Self-Efficacy	3.78	.03	.16	Intro vs. Inter	-0.86	-2.19	.09	-0.82	[-1.79, 0.14]
				Intro vs. Adv	-0.90	-2.35	.06	-0.86	[-1.80, 0.09]
				Inter vs. Adv	-0.04	-0.09	.99	-0.09	[-1.08, 1.01]
Utility Value	4.75	.01	.19	Intro vs. Inter	-0.96	-2.32	.06	-0.87	[-1.84, 0.10]
				Intro vs. Adv	-1.10	-2.74	.03*	-0.99	[-1.95, -0.04]
				Inter vs. Adv	-0.14	-0.31	.95	-0.13	[-1.17, 0.92]

Note. p value and confidence intervals adjusted using Tukey correction. Intro = Introductory, Inter = Intermediate, Adv = Advanced.

* $p < .05$.

FIGURE 2

Plot of Pretest Scores by Teaching Condition



Note. Graph generated by JASP.

$F(2, 37) = 0.50$, partial $\eta^2 = .03$. Taken separately, teaching method failed to reach significance, $F(1, 37) = 2.00$, $p = .17$, partial $\eta^2 = .05$ (see Figure 3), but education level was significant, $F(2, 37) = 3.96$, $p = .03$, partial $\eta^2 = .18$ (see Figure 4). Post-hoc tests with Tukey corrections showed only marginally significant differences between introductory and intermediate students, $M_{diff} = -0.87$, $t(2) = -2.30$, $p_{corr} = .07$, Cohen's $d = -0.89$, 95% CI [-1.89, 0.11], and introductory and advanced students, $M_{diff} = -0.84$, $t(2) = -2.33$, $p_{corr} = .06$, Cohen's $d = -0.85$, 95% CI [-1.80, 0.10]. There was no significant difference between intermediate and advanced students, $M_{diff} = 0.04$, $t(2) = 0.08$, $p_{corr} = .99$, Cohen's $d = 0.04$.

Motivation

Multivariate analyses of variance (MANOVAs) were conducted to investigate the effect of teaching methodology and education level on the subscales of motivation assessed by the MMQ. Due to insufficient observations when grouping by both teaching condition and education level, each factor was analyzed separately. Descriptive statistics for each subscale across education level are provided in Table 5.

The MANOVA for education level was significant, Wilks' Lambda = .59, $F(2, 40) = 2.16$, $p = .03$, indicating a difference between the groups on students' motivation across subscales. Follow up univariate ANOVAs showed education levels were significantly different ($p < .05$) on three subscales: self-regulation, self-efficacy, and utility value (see Table 6); there was no significant difference regarding intrinsic value, $F(2, 40) = 0.88$, $p = .42$, and test anxiety, $F(2, 40) = 0.21$, $p = .82$. Tukey's HSD test revealed significant differences ($p_{corr} < .05$) between the introductory and advanced students on self-regulation ($M_{diff} = -0.97$, $p_{corr} = .02$) and utility value ($M_{diff} = -1.10$, $p_{corr} = .03$), and a marginal but nonsignificant difference on self-efficacy ($M_{diff} = -0.90$, $p_{corr} = .06$). There was no significant difference between the traditional and modern teaching methods across the five subscales, Wilks' Lambda = .86, $F(1, 41) = 1.25$, $p = .31$.

Discussion

The goal of this study was to investigate the impact of different teaching methods on mathematical achievement and motivation in college students across various levels of collegiate mathematical education. The hypotheses predicted that students exposed to modern teaching methods would demonstrate higher scores in both achievement and motivation compared to their counterparts in the traditional teaching group. Additionally, it was expected that students with advanced mathematical experience would outperform those at intermediate levels, and so on for those at introductory levels.

Influence of Teaching Method

Contrary to other studies with similar college student participants such as Roop et al. (2018) and Voskoglou (2019), teaching method had little to no effect on achievement and motivation. Although there was a general improvement from pretest–posttest, the relative improvement was similar across the teaching conditions with near-equal effect sizes (see Table 4). Another possible explanation for the lack of differences may lie in the challenges of delivering content effectively within the constraints of relatively short instructional periods. This time limitation may have hindered students' ability to develop a deeper understanding of the material, regardless of the teaching method used.

It is important to also note the bimodal distribution of posttest scores of the modern group as seen in Figure 3. An exploratory Mann-Whitney U test—a weaker test than the t -test that is not reliant on the assumption of normality and is better suited for smaller sample sizes—indicates there is in fact some significant difference between the two teaching conditions, $W = 319.50$, $p = .03$, rank-biserial correlation = .38, 95% CI = [.05, .64], confirming our visual inspection. This divergence from a unimodal pretest distribution to a bimodal posttest distribution within the modern group warrants further investigation into the factors that may influence this trend.

Additionally, variations in the composition of participants across different instructional sessions may have contributed to the absence of significant findings. Factors such as pre-existing familiarity between students and potential instructor biases (as the researcher also acted as the instructor) could have introduced unintended variations in student experiences. However, when asked if the method of instruction was similar to their current enrolled course, 52% of those in the traditional group either agreed or strongly agreed, whereas 63% in the modern group disagreed or strongly disagreed, which was significantly different, $t(38) = 2.48$, $p = .02$, Cohen's $d = 0.79$, 95% CI = [0.13, 1.42]. Even though the students were not informed of their condition prior to the study, the majority of participants in the modern group noted a difference in teaching approach when compared to their current course's instruction. This perception of teaching method may possibly help explain the divergence in posttest scores mentioned previously, though future studies on perceived instructional method would need to further uncover this relationship.

Although differences were not reliably found between groups, it has been noted that having a wide range of instructional techniques is beneficial for students to gain developed and nuanced understanding that leads to eventual content mastery (San & Kis, 2018; Umugiraneza et al., 2017). Having a rich vocabulary of technical skills

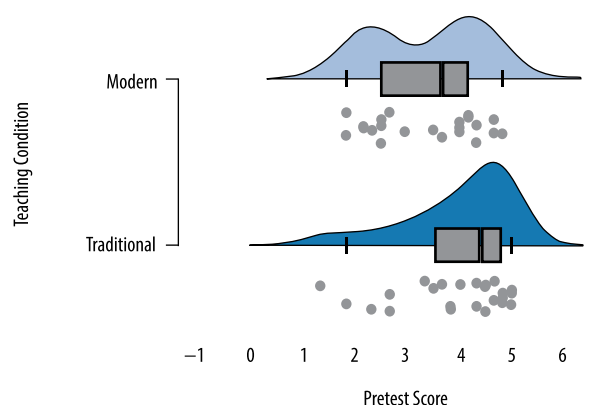
and instructional methods could prove beneficial for instructors of students of all ages, not just in higher education. Further research is needed to critically examine what techniques are utilized by professors and educators alike, how they came to use the particular instructional techniques implemented in their classroom, and how the cycle of education may perpetuate ineffective or outdated practices due to ease of use and application.

Education Level and Mathematical Motivation

The analysis revealed a noteworthy relationship between educational level and student motivation, where intermediate and advanced students exhibited higher motivational

FIGURE 3

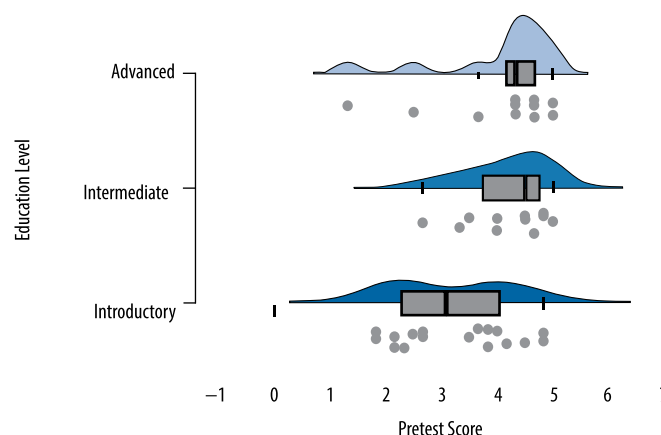
Plot of Posttest Scores by Teaching Condition



Note. Graph generated by JASP.

FIGURE 4

Plot of Posttest Scores by Education Level



Note. Graph generated by JASP.

scores, particularly regarding self-regulation, self-efficacy, and utility value (Table 6). This finding suggests that as students progress through their mathematical education, they may develop greater responsibility for studying math concepts (Brown & Hirschfeld, 2007), see themselves as capable of performing mathematical tasks (Ayotola & Adedeji, 2009), and gain a stronger understanding of its usability (Petersen & Hyde, 2017). Although not significant, there was a general increase in intrinsic value and corresponding decrease in test anxiety as educational level increased, which is consistent with contemporary research (Li et al., 2021).

Although previous studies have typically examined cohorts of students within the same course or grade level (see Akcakin, 2017; Damrongpanit, 2019) or focused on the perceptions of the teachers on student motivation and the effect of their practices (Damrongpanit, 2019; Hidalgo-Cabrillana & Lopez-Mayan, 2018; Umugiraneza et al., 2017), we were able to demonstrate how the level of education within the undergraduate framework affects motivation toward learning mathematics. Future research should further investigate mathematical motivation's development over time, both in degree programs heavy with mathematics materials as well as those that adjacently work with mathematical concepts.

Limitations

The most apparent limitations stem from the relatively small sample size and the specific context of a private liberal arts college in Arkansas. To have an appropriately powered independent samples test at around .80, at least 64 participants would have been needed in each group. Though the exploratory Mann-Whitney *U* test mentioned earlier notes a significant difference in distribution shape between the two conditions, further studies with larger sample sizes should be conducted to verify and validate the present results. Despite the small sample size, the study participants were largely representative of the greater college demographics in terms of the distribution of race and gender. Preliminary analyses of these populations showed no significant effect on the measured outcomes, but it is important to note historical disparities in education that unequally disadvantage those of historically marginalized backgrounds (Roop et al., 2018).

Additionally, there was some skew in terms of the percentage of majors and non-majors in the study, with participants classified as advanced students consisting of exclusively math majors and those classified as introductory overwhelmingly consisting of non-majors; however, the intermediate group was split evenly between the two groups. Although this was expected and anticipated via the operationalization of education level, further

investigation is needed to determine how the two groups comparatively operate, particularly toward their mathematical motivation. However, the current study may resonate and generalize to other similar smaller higher education institutions as a particular case study. Another context-specific limitation concerns the specific content covered. While the content was drawn from an advanced combinatorics course, the concepts covered – the basic counting principle, permutations, and combinations, see Table 2 – are introductory topics that are commonly taught in other courses, such as discrete mathematics, probability, and statistics, though at varying stages within the course.

It is also important to note the MANOVA assumption of multivariate normality was violated regarding the motivation scores across education level and teaching condition analyses as a result of the small sample size. Following the discussion by Ates et al. (2019), Wilk's Lambda should be robust enough to detect difference in the event of unbalanced observations in the sample (for more discussion on when to use different MANOVA statistics when assumptions are violated; see Olson, 1974, 1976, 1979). Additionally, the primary purpose of the MANOVA was to be an initial examination of the overall effect of motivation; the significant result prompted the follow-up ANOVAs on the individual motivation subscales to better understand which ones specifically contributed to the overall effect of motivation observed. It is acknowledged that the assumption violation may introduce some uncertainty in the results. However, significant findings in the subsequent post-hoc ANOVAs provide evidence of significant differences in motivation between education levels.

Conclusion

Overall, this study investigated the influence of teaching method on the mathematical achievement and motivation of college students. It is important to acknowledge the context, scope, and limitations in the interpretation of results. Further iterations of this line of research could include longitudinal studies that examine development of mathematical achievement over time as concepts and techniques increase in complexity. Additionally, collaborations across departments or institutions to implement experimental conditions in several locations could produce significant results, as well as increasing the diversity of the sample population. The novelty effect noted in some modern teaching methods, which initially pique students' interest, could be addressed through long-term studies that measure changes in motivation and achievement over time, providing a more comprehensive picture of the lasting impact of instructional approaches (Tularam & Machisella, 2018).

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