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RESEARCH ARTICLE

The impact of the stratified cognitive apprenticeship model on mathematical motivation in high school students

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ABSTRACT

This study investigated the impact of a Stratified Cognitive Apprenticeship Model Teaching Module (SCTM) on the mathematical learning motivation of high school students in China. Using a quasi-experimental design, the study was conducted in a high school with 150 ninth-grade students, who were randomly divided into three groups. The first treatment group employed the Cognitive Apprenticeship Model (CAM) teaching strategy, wherein teachers used modelling, coaching, scaffolding, articulation, reflection, and exploration strategies. The second treatment group implemented SCTM teaching, in which students were stratified by their performance ability level and the class was designed following the CAM process. The control group maintained Conventional Instruction (CI), including lectures, note-taking, and homework completion. Motivational assessments were administered to students according to the pretest, post-test, and delayed post-test to evaluate the effects of CAM and SCTM on student learning motivation. The results confirmed through Analysis of Covariance (ANCOVA) demonstrated that the SCTM group outperformed the CAM group, which in turn outperformed the traditional teaching group. These findings provide empirical support for high school mathematics education, proving that teaching strategies combining stratification and the cognitive apprenticeship model can effectively enhance students' learning motivation.

Ethical Compliance: All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional an national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Keywords: Stratified Cognitive Apprenticeship Model Teaching Module (SCTM); Cognitive Apprenticeship Model (CAM); high school mathematics motivation; Quasi-experimental design

1. Introduction

Educational psychology has long recognized the pivotal role of learning motivation, which serves as the internal force driving students to engage in and sustain learning activities, thereby influencing educational outcomes[25]. Originating from the Latin word "movere," which means "to move," motivation encapsulates the essence of this compulsion in education[5]. Various academic definitions underscore the dynamic nature

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of motivation and its critical role in promoting active student participation in educational activities[6].

In the realm of mathematics education, traditional teaching methods often fail to accommodate the individual differences and specific needs of students, thereby lacking adequate support[13]. This issue is accentuated under China's new curriculum reform, which emphasizes "communication" and "interaction" in classroom teaching, urging teachers to adopt more interactive instructional models to enhance understanding and mathematical literacy[31]. One significant problem in China's math classrooms is the lack of student motivation, which is often attributed to the persistence of traditional, teacher-centered instructional methods, despite recent curriculum reforms aimed at promoting more student-centered approaches[37].

Teacher-student interaction is vital for student motivation and learning, with research indicating that teacher leadership and granting students more freedom can boost students' emotions and improve their math achievement, though traditional teacher-centered methods may hinder engagement[14]. Motivation and engagement are essential for mathematics achievement, but in China, primary students' levels of motivation and engagement are often shaped by factors like teaching methods and the classroom environment, with traditional practices such as rote learning and high-stakes testing sometimes reducing student motivation[40].The core principle of (Cognitive Apprenticeship Model) is to promote students' self-directed learning using methods such as imitation, coaching, exploration, and reflection[3]. CAM prioritizes the implementation of techniques such as modelling, coaching, and scaffolding to assist students in comprehending the procedure of accomplishing tasks, which improves their ability to think for themselves and drive themselves[24]. The Cognitive Apprenticeship Model (CAM) enhances student learning motivation by integrating real-world clinical exposure with guided learning strategies, such as modeling, coaching, and reflection, which significantly improves students' motivational self-regulation skills[26].

To address the deficiencies of traditional methods and align with modern educational mandates, this study introduces the Stratified Cognitive Apprenticeship Model Teaching Module (SCTM). This approach integrates the Cognitive Apprenticeship Model (CAM) with stratified teaching strategies to tailor instruction to meet diverse student needs through the systematic application of modeling, coaching, scaffolding, articulation, reflection, and exploration. These strategies were designed to promote self-directed learning and improve student motivation in high school mathematics. The literature reveals that innovative teaching strategies significantly impact student motivation. Researchers have identified stratified instruction and personalized learning approaches as effective in enhancing motivation and academic achievement, providing tailored support and challenges suited to varying learning levels[20].

SCTM, which combines the cognitive apprenticeship model with stratified teaching strategies, aims to meet students' diverse learning needs through personalized and differentiated instructional methods. To use this method, students are first put into groups based on their performance level, and then the Cognitive Apprenticeship Model (CAM) is used to help them learn how to learn on their own through strategies like modeling, coaching, exploring, and reflecting.

Collins et al. identified the six core features of a cognitive apprenticeship[3]:

(1) **Modeling** is when the student watches the teacher complete a task.

(2) **Coaching:** the teacher observes the student complete a task and offers suggestions and feedback.

(3) **Scaffolding** refers to the learning support provided to the student by the teacher, ranging from brief lessons to physical learning tools, such as simulations.

(4) **Articulation** refers to the methods the teacher uses to encourage students to verbalize their thought processes as they explicitly complete a task.

(5) **Reflection** occurs when students compare their skill level and ability to complete a task to that of the teacher.

(6) **Exploration** occurs when advanced students are guided to develop solutions to a problem or a task completion method. Combining these principles in an educational setting defines cognitive apprenticeship and allows teachers to pass down skills that require technical expertise and high-level thinking.

2. Study aim and gap

Previous studies have primarily focused on either innovative teaching strategies or cognitive apprenticeship principles in isolation, without exploring their integrated impact on student motivation and engagement. This study aims to bridge this gap by investigating the effects of the Stratified Cognitive Teaching Model (SCTM) on high school students' learning motivation. Additionally, it explores how stratified instruction based on cognitive apprenticeship models can sustain and enhance learning motivation, providing a more holistic approach to mathematics education.

3. Methodology

3.1. Participants

This study involved a cohort of 150 ninth-grade students enrolled in a high school in China known for its emphasis on progressive educational strategies and academic excellence. Participants were selected based on their enrollment in a mandatory mathematics course, ensuring that all individuals shared a common educational background. This selection process aimed to minimize external variability and to focus on the effects of instructional strategies.

3.2. Instruments and measurements

This study applied the Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich et al.[21] to assess distinct aspects of motivation among mathematics students. This research utilizes the Motivated Strategies for Learning Questionnaire (MSLQ) to examine achievement motivation, focusing on intrinsic and extrinsic goal orientations, task value, and control of learning beliefs as key contributors[21] to academic success. The MSLQ measures these constructs using a seven-point Likert scale, enabling a nuanced analysis of the factors that enhance or impede student engagement and learning outcomes[16]. For instance, intrinsic goal orientation is quantified through the mean scores of four pertinent items, reflecting the degree to which students are motivated by personal satisfaction or a deep interest in their learning tasks.

This study looks at intrinsic motivation, which is how much students are driven by their own desire to master math concepts, their natural curiosity, and the difficulties that come with them. This is similar to how McKeachie et al.[16] defined it, and Ryan and Deci[27] added personal interest and enjoyment in learning to that list.

Extrinsic Goal Orientation reflects how external rewards, such as grades and peer recognition, motivate students. This construct follows that of McKeachie et al.[16] and was detailed by Wigfield and Eccles[39] as a motivation driven by external accolades and competitive success.

Task Value is defined as the perceived interest in, importance of, and utility of mathematics coursework. It is differentiated from goal orientation by focusing on the task's inherent benefits rather than the reasons for engagement[5].

Control of Learning Beliefs assesses students' convictions about their efficacy in using personal effort and strategies to achieve successful outcomes in their studies, as delineated by McKeachie et al.[16].

Each of these dimensions is critically analyzed to understand their impact on students' engagement and performance in mathematics, providing insights into how motivational factors can be strategically enhanced to improve educational outcomes.

3.3. Design and procedure

This study employed a quasi-experimental pretest design to evaluate the impact of stratified teaching based on the cognitive apprenticeship model (SCTM) on the learning motivation of Chinese high school students. The motivational aspects assessed included intrinsic and extrinsic goal orientations, task values, and control of learning beliefs. The challenges of implementing random assignments in real-world educational settings necessitate their design.

Each group consisted of 50 students learning the mathematical concepts of functions and relations. The control group used a conventional lecture-based teaching approach, in which students passively received information, took notes, and completed their homework. By contrast, the CAM and SCTM groups engaged in active learning and student engagement strategies.

CAM employs cognitive apprenticeship principles, treating teachers as experts and students as novices[3]. This model facilitates learning through demonstration, scaffolding, coaching, and cooperation. In modeling, the student observes the teacher performing a task. Coaching occurs when the teacher watches the student execute the task and provides feedback. Scaffolding is when the teacher provides learning support, such as lessons and tools. Articulation encourages students to verbalize their thought processes during a task. Reflection allows students to compare their skills with those of the teacher. Exploration teaches advanced students how to solve problems on their own. Together, these steps form a cognitive apprenticeship, facilitating skill transmission.

This encourages students to externalize and apply their cognitive processes to complete tasks, solve problems, and transfer their skills to various fields.

SCTM builds on CAM by incorporating a stratified approach based on students' ability levels, enhancing the cognitive apprenticeship framework to more effectively personalize and optimize learning outcomes according to individual capacities.

In this quasi-experimental study, as the **Figure 1** shows, three groups of 50 students each were established to evaluate the effects of different teaching methods on. Group 1 (control group) received conventional instruction (CI) using traditional teaching methods. Group 2 was taught using the Cognitive Apprenticeship Model (CAM), and Group 3 used a stratified approach based on CAM, known as the Stratified Cognitive Apprenticeship Teaching Modules (SCTM). All groups underwent a pretest to assess mathematics performance, problem-solving skills, and motivation, which were covariates in the analysis. Following an 8-week instructional period, a post-intervention assessment was conducted to measure the same outcomes. Two weeks later, a delayed post-test was administered to evaluate the retention and long-term impact of the educational interventions on students.

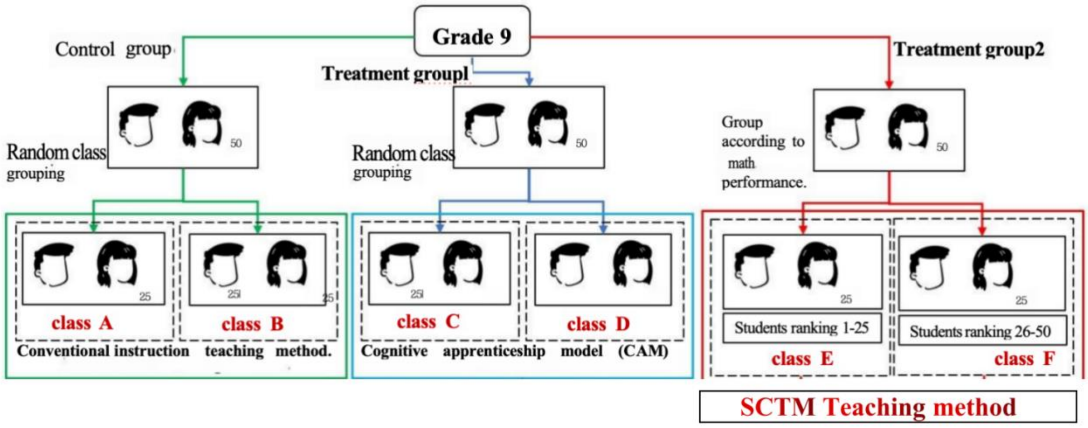

Figure 1. Quasi-experimental design for assessing different teaching methods.

3.4. Motivated Strategies for Learning Questionnaire (MSLQ)

The MSLQ, a well-established self-report instrument, was employed to evaluate students' motivation and utilization of various learning techniques. The MSLQ took social cognitive theories of motivation and self-regulated learning[25] and was first created by McKeachie et al.[16]. It was then improved by Pintrich et al. in the late 1980s and early 1990s[21]. This tool was designed to assess intrinsic and extrinsic goal orientations, task value, beliefs about learning, self-efficacy for learning and performance, and test anxiety. Each of the 81 items in the MSLQ is rated on a seven-point Likert scale ranging from 'strongly disagree' (1) to 'strongly agree' (7), enabling a nuanced analysis of students' motivational dynamics, as shown in the appendix.

This study focused on four constructs from the motivation component, utilizing 16 items to assess intrinsic goal orientation, extrinsic goal orientation, task value, and control of learning beliefs. The subscales and specific items are presented in **Table 1**.

Table 1. Rubric developed to assess motivation competence.

Subscales	Scale	Items in the Subscale
Motivation Subscales	Intrinsic Goal Orientation	1,16,22,24
	Extrinsic Goal Orientation	7,11,13,30
	Task Value	4,10,17,23,26,27
	Control of Leaning Beliefs	2,9,18,25

To ensure internal consistency of the MSLQ, Cronbach's α was computed for each selected item and subscale. The reliability analysis indicated good internal consistency across the pretest, post-test, and delayed post-test phases, as shown in **Table 2**. In the initial assessment phase, the Motivated Strategies for Learning Questionnaire (MSLQ) exhibited a Cronbach's alpha of .694 in the pre-test, which is slightly below the commonly accepted threshold for adequate reliability. Cronbach's alpha of .70 or above is typically considered acceptable, indicating good internal consistency, values between .60 and .70 may still be acceptable.[7]. The lower alpha value in the pre-test phase could reflect participants' initial adjustment to the assessment tool or a less cohesive set of motivational constructs at the beginning of the study.

Although the reliability score was lower during the pre-test phase, an increase in Cronbach's alpha values in subsequent evaluations (post-test and delayed post-test) indicated that the reliability of the MSLQ improved as participants became more familiar with the questionnaire format and constructs being measured.

This improvement supports the tool's efficacy in our study, confirming its applicability in measuring dynamic changes in learning motivation.

Table 2. Reliability analysis of MSLQ.

Variables	Number of items	Cronbac'α coefficient
Pretest	22	0.694
Post-test	22	0.778
Delayed post-test	22	0.820

3.5. Data analysis

In this study, data analysis was conducted using SPSS software and included both descriptive and inferential statistical methods. Initially, normality checks were performed to verify data distribution. Descriptive analysis summarized the dataset's main characteristics, focusing on mean and standard deviation. After controlling for confounding factors, ANCOVA inferential analysis determined significant differences among groups. This approach ensured statistically valid and meaningful conclusions within educational research.

3.5.1. Descriptive statistics

In the initial data analysis phase, descriptive statistics were employed to identify the primary characteristics and distribution of the dataset. The normality of the data was assessed using the Kolmogorov-Smirnov test, as well as the calculation of skewness and kurtosis. Additionally, visual inspections were conducted using histograms, box plots, P-P plots, and Q-Q plots to confirm the presence of a normal distribution in the data.

Descriptive statistics were used to delineate the sample attributes. This project gathered data on the mathematical learning motivation of 150 high-school students. Students were categorized into three strategy groups: CI, CAM, and SCTM. The researchers calculated the post-test results' mean and standard deviation (SD) to assess the central tendency and variability in each approach group.

3.5.2. Inferential analysis

The selected analytical approach for this inquiry was Analysis of Covariance (ANCOVA), where the teaching technique was considered the independent variable, and the overall mathematics performance score and scores on the previously indicated specific features were the dependent variables. This approach considered confounders and detected disparities in the means of the dependent variables among instructional strategies. This study rigorously assessed the dataset's adherence to the ANCOVA assumptions using established statistical methods to ensure the reliability of the findings.

4. Results

Learning motivation is an indispensable part of the student learning process that directly affects long-term academic achievement[3]. Therefore, this section will analyze the effects of CAM, SCTM, and CI strategies on learning motivation in the posttest and delayed posttest.

Certain assumptions must be met for the ANCOVA to be applied accurately and reliably. As elucidated by Tavakoli[28], these assumptions are pivotal for ensuring the authenticity of ANCOVA results. With the dataset defining the "Group" as the categorical independent variable and "Pre" as the covariate, the essential assumptions of a linear relationship between the dependent variable and covariate and the homogeneity of the regression slopes become critical[19].

4.1. ANCOVA assumptions

To ensure a solid foundation for conducting an ANCOVA, it is essential to confirm that all the necessary assumptions are met. This section discusses the fundamental prerequisites for ANCOVA, focusing on the normality of the dependent variable across different testing phases.

Table 3. Normality analysis for dependent variables.

Dependent variables		N	Kolmogorov-Smirnov		
			statistics	P value	Hypothesis
Learning motivation	Pretest	150	.062	.200 (p ≥ .05)	Accepted
	Post-test	150	.090	.005 (p ≤ .05)	Rejected
	Delayed post test	150	.062	.200 (p ≥ .05)	Accepted

Table 3 is based on all p-values, except that the learning motivation test of the post-test was above the conventional threshold of 0.05, suggesting no substantial deviation from normality[5]. As a result, except for the post-test learning motivation, the hypothesis of normality is accepted. Because of its deviation from normality, additional nonparametric tests or transformations should be considered for the learning motivation post-test.

Learning motivation

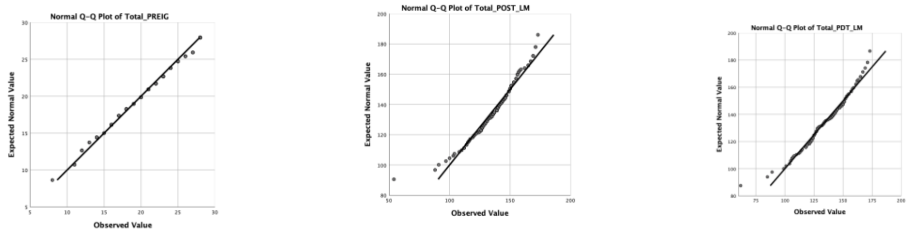

Figure 2. Q-Q plot for dependent variables.

PRE:Pretest for Learning motivation

POST_LM:Post test for Learning motivation

PDT-LM:Post delayed test for Learning motivation

As shown in **Figure 2**, the points on the Q-Q plot roughly fall on a straight line. Therefore, the data conformed to normal distribution.

Learning motivation

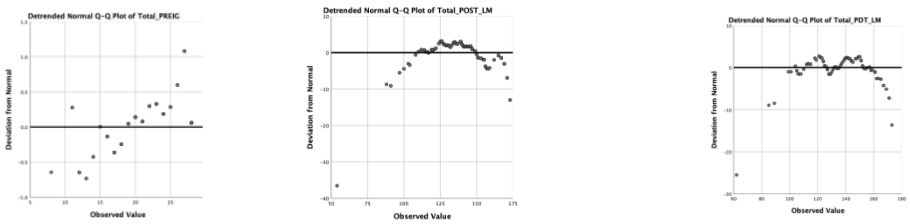

Figure 3. Detrend Q-Q plot for dependent variables.

As shown in **Figure 3**, the detrended Q-Q plot is an enhanced form of the conventional Q-Q plot specifically designed to reveal subtle deviations from an expected, typically normal distribution. In such a plot, if the data closely adhere to normality, the plotted points should fluctuate around the zero line (y=0), with no discernible systematic trend. An examination of **Figure 3** reveals that most of the data points align with this expected pattern. This consistent oscillation near the horizontal axis suggests that the data set approximates a normal distribution.

Table 4. Regression slope homogeneity test for interaction between group and covariate across different tests.

Tests	Dependent Variable	Type III Sum of Squares	Mean Square	F	Sig.
Learning motivation	Post-test	9270.943	3090.314	11.427	.000
	Delayed post-test	16900.054	5633.351	23.075	.000

For learning motivation, as **Table 4** shows, the post-test and the delayed post-test had p-values of .000, suggesting substantial interactions between the group and the covariate for this performance measure.

4.2. Descriptive analysis

Analyzing shifts in mean scores helps us understand how different teaching strategies affect student motivation over time. The subsequent figures and tables provide a detailed view of these trends across the various motivational dimensions.

Table 5. Descriptive statistics of motivation scores and subscales at pre-test, post-test, and delayed post-test.

V	Group	Pre-test Mea(SD)	Post-test Mean (SD)	Delayed Post-test Mean (SD)
L	CI	80.22(13.68)	82.14 (12.80)	79.54(14.09)
	CAM	80.58(13.10)	88.42 (14.81)	88.38(14.32)
	SCTM	82.98(11.24)	95.02 (10.04)	95.32(11.20）
I	CI	20.50(4.51)	20.96(4.13)	19.90(4.51)
	CAM	20.32(4.25)	22.78(4.29)	22.42(4.38)
	SCTM	22.18(5.45)	22.54(4.53)	24.16(3.74）
E	CI	21.02(4.11)	21.04 (3.83)	20.54(4.24)
	CAM	21.08(3.96)	22.42 (4.67)	21.82(4.61)
	SCTM	21.90(4.39)	23.90 (4.39)	22.32 (3.50)
T	CI	18.62(4.69)	19.78 (3.73)	19.06 (4.74)
	CAM	18.68(4.45)	20.08 (4.15)	21.56 (4.50)
	SCTM	19.24(3.91)	22.24 (3.91)	23.90 (4.63)
C	CI	20.08(4.10)	20.37 (3.91)	20.04 (4.20)
	CAM	20.50(4.12)	23.14 (3.87)	22.58(4.06)
	SCTM	19.66(4.86)	24.34 (4.46)	23.94 (3.20)

Note: *V: Variables; L: Learning Motivation; Subscale: I: Intrinsic Goal Orientation; E: Extrinsic Goal Orientation; T: Task Value; C: Control of Learning Beliefs*

Table 5 illustrates that the Stratified Cognitive Apprenticeship Teaching Modules (SCTM) notably enhanced scores across various dimensions, especially in learning motivation and intrinsic goal orientation. For instance, in the dimension of learning motivation, the pre-test average score for SCTM was 82.98, which increased to 95.02 in the post-test and further slightly to 95.32 in the delayed post-test. This demonstrates a sustained positive impact on students' motivation, attributable to the SCTM approach.

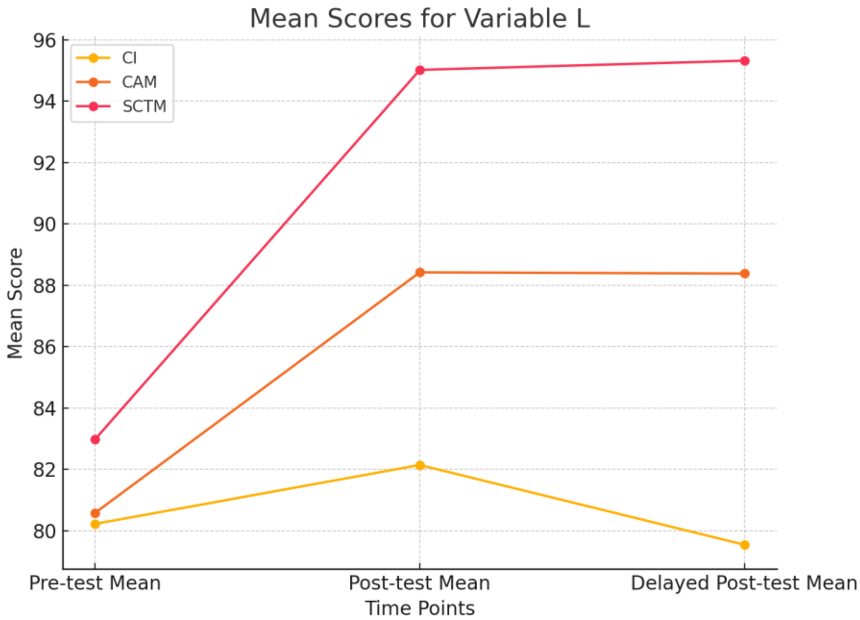

Figure 4. Mean "motivation" scores by teaching method over time.

Figure 4 illustrates that the SCTM group exhibited a steep rise in learning motivation scores from pre-test to post-test, maintaining high scores in the delayed post-test. This indicates that the SCTM approach is particularly effective in boosting and sustaining students' motivation. The CI group showed minimal changes, suggesting that conventional instruction may not be as effective in significantly enhancing learning motivation. The CAM group showed moderate improvement, and was positioned between the CI and SCTM groups.

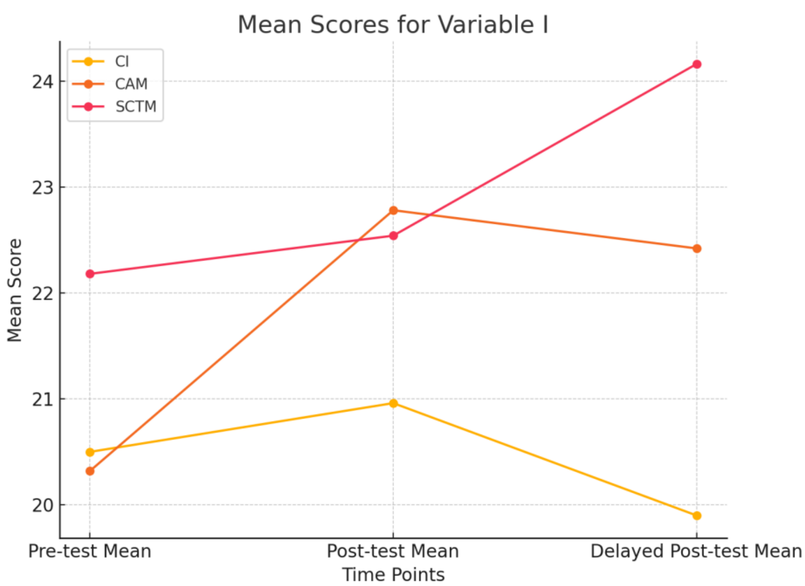

Figure 5. Mean "intrinsic goal orientation" scores by teaching method over time.

As shown in **Figure 5**, the SCTM group's scores on "intrinsic goal orientation" not only sustain but also enhance their performance over time, suggesting a highly effective intervention or condition that led to robust learning and retention. The CI group, however, struggles to maintain its initial improvement, showing a regression that could imply ineffectiveness or even a negative impact of the applied condition. The CAM group lies somewhere in between, with a strong initial improvement that partially diminishes over time, indicating some level of retention, though not as much as the SCTM group. These patterns provide valuable insights into the relative effectiveness of the different interventions or conditions applied to each group, highlighting the importance of sustained impact for long-term success.

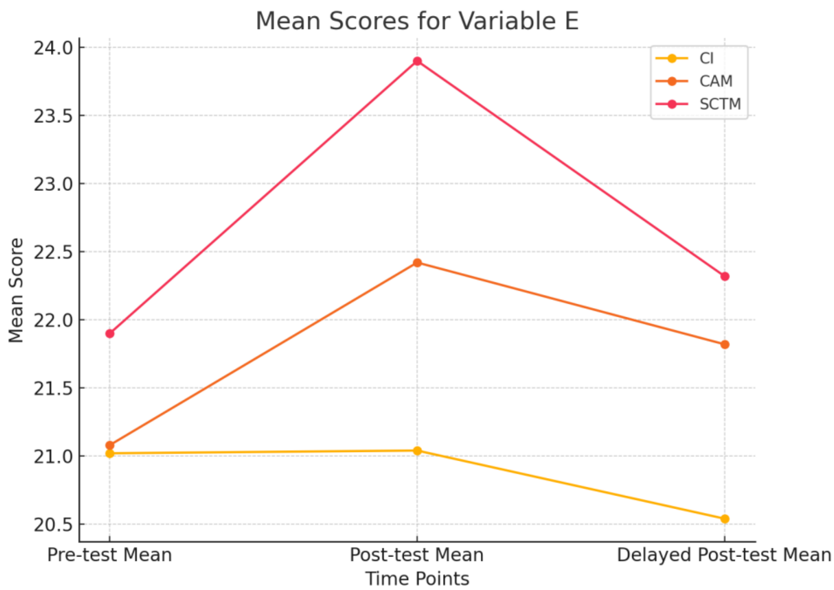

Figure 6. Mean " extrinsic goal orientation" scores by teaching method over time.

For extrinsic goal orientation, As shown in **Figure 6**, the SCTM group showed the most substantial improvement following the intervention, with a significant increase in mean scores from Pre-test to Post-test. Although there was a slight decline in the Delayed Post-test, the SCTM group still maintained the highest scores compared to the other groups. The CAM group also showed improvement, but with partial retention over time, as their scores slightly decreased after the Post-test. In contrast, the CI group displayed minimal improvement with a small decline in scores by the Delayed Post-test, suggesting that the intervention was less effective for this group.

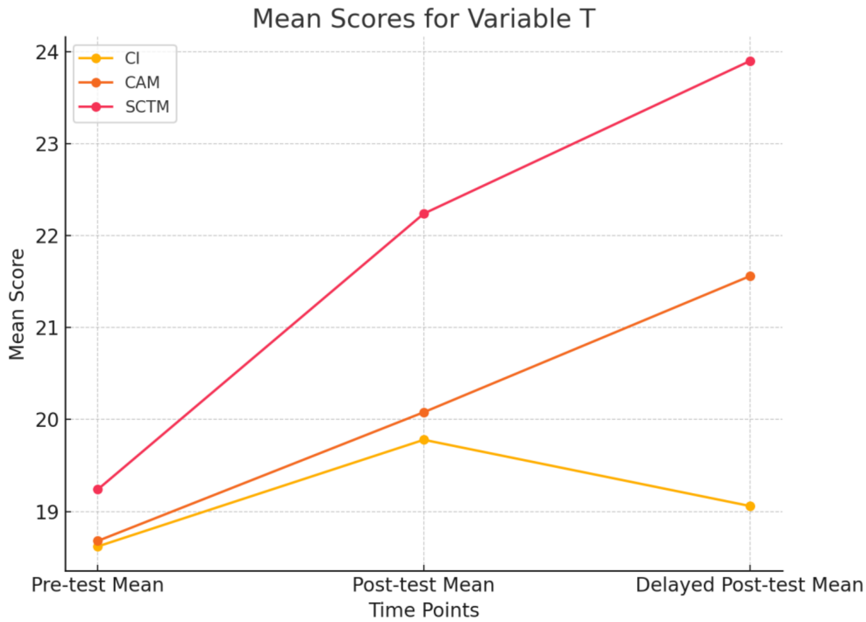

Figure 7. Mean "task value" scores by teaching method over time.

As shown in **Figure 7**, The SCTM group showed a significant and consistent upward trajectory in task value, suggesting that students perceived their learning tasks as more valuable and relevant over time. The CAM group also showed improvement, although to a lesser extent than the SCTM group, while the CI group's scores remained relatively flat across all phases, indicating a lesser impact on the students' valuation of tasks.

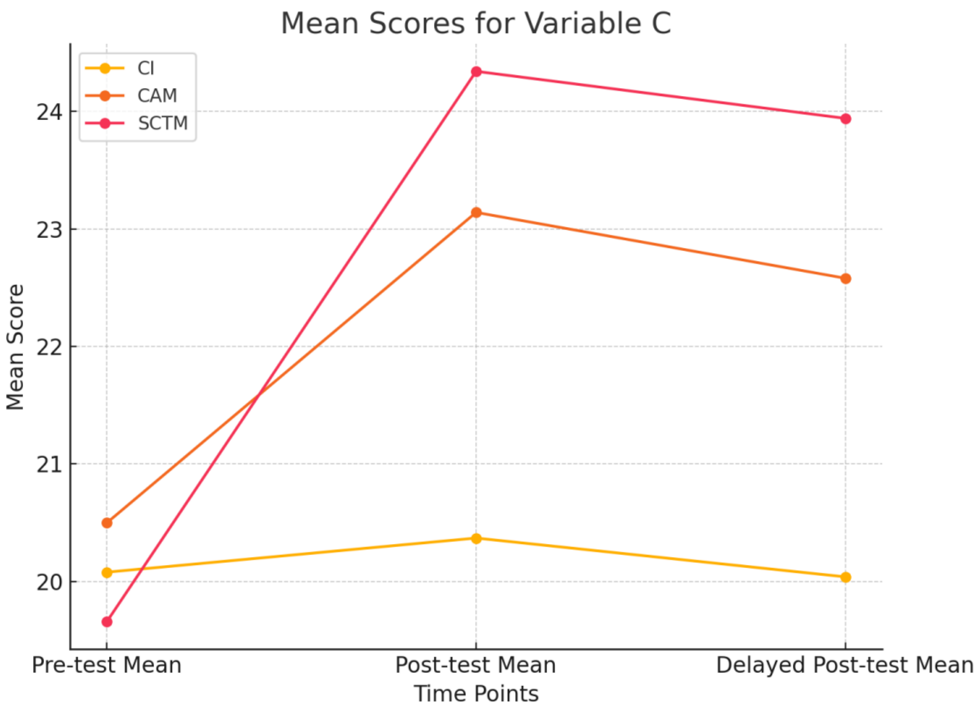

Figure 8. Mean "control of learning beliefs" scores by teaching method over time.

As shown in **Figure 8**, SCTM significantly boosted students' beliefs in their ability to control their learning outcomes, with scores peaking in the post-test and declining slightly in the delayed post-test. The CI group showed minimal change, whereas the CAM group exhibited a slight improvement, again positioning SCTM as the most effective method for enhancing and maintaining control over learning beliefs.

Across these variables, the SCTM group generally showed a significant improvement in the post-test, which was often sustained or slightly declined by the delayed post-test, indicating the effectiveness of the scaffolded case-based multimedia approach in enhancing and maintaining these educational attributes. The CI group typically exhibited fewer significant changes across the test phases, whereas the CAM group often showed moderate improvement, positioning it between the CI and SCTM groups. These trends suggest that more interactive and structured instructional strategies such as SCTM boost initial learning outcomes and have a lasting impact on students' educational attitudes and beliefs across various dimensions.

4.3. Effect of instructional strategies on motivation

Analysis of the impact of various teaching strategies on student motivation involved ANCOVA assessments for both the post-test and delayed post-test phases. This summary highlights how different approaches affect learning motivation over time, emphasizing the significant differences between the CI, CAM, and SCTM groups, as demonstrated by the statistical results.

Table 6. Summary of ANCOVA and post-hoc results for learning motivation across test phases.

Test Phase	Source	F Value	p-value	Comparison	Mean Diff.	p-value	95CI Lower	95% CI Upper
Post-Test	Model	12.132	< .001	CI vs SCTM	-12.455	< .001	-18.578	-6.331
				CI vs CAM	-6.225	.044	-12.324	-0.125
				CAM vs SCTM	-6.230	.044	-12.348	-0.113
Delayed Post Test	Model	17.693	< .001	CI vs SCTM	-14.724	< .001	-19.673	-9.775
				CI vs CAM	-8.702	.002	-13.641	-3.763
				CAM vs SCTM	-6.022	.050	-11.000	-1.044

As shown in **Table 6**, the application of ANCOVA revealed the significant effects of instructional strategies on learning motivation, as evidenced by the results of both the post-test and delayed post-test phases. The analysis demonstrated a robust impact, with the SCTM strategy showing particularly strong effects. Notably, the CI vs. SCTM comparison indicated substantial improvements in learning motivation, with differences of -12.455 ($p < .001$) in the post-test and -14.724 ($p < .001$) in the delayed post-test, suggesting the effectiveness of the SCTM strategy in significantly enhancing motivation over other strategies.

4.4. Effect of instructional strategies on "intrinsic goal orientation"

The analysis incorporated a comparison of teaching strategies in terms of their impact on students' intrinsic goal orientations. The findings presented below illustrate the effectiveness of these strategies at various stages of assessment, highlighting significant improvements, particularly in the SCTM approach.

Table 7. Combined ANCOVA and post-hoc results for intrinsic goal orientation.

Test Phase	Source	F Value	p-value	Comparison	Mean Diff.	p-value	95% CI Lower	95% CI Upper
Post-Test	Model	9.950	< .001	CI vs CAM	-1.864	.081	-3.510	0.782
				CI vs SCTM	-3.169	.001	-4.832	-1.506
				CAM vs SCTM	-1.305	.375	-2.972	0.362
Delayed Post-Test	Model	13.323	< .001	CI vs CAM	-2.520	.002	-4.250	-0.790
				CI vs SCTM	-4.260	< .001	-6.004	-2.516
				CAM vs SCTM	-1.740	.046	-3.488	-0.008

From **Table 7**, In the evaluation of the impact of instructional strategies on intrinsic goal orientation, both immediate and delayed assessments showed significant model effects (Post-Test: F = 9.950, p < .001; Delayed Post-Test: F = 13.323, p < .001). Notably, post-hoc pairwise comparisons revealed differential impacts among the strategies. In the post-test, the CI vs. SCTM comparison was particularly significant, showing a mean difference of -3.169 (p = .001), suggesting a strong influence of the SCTM strategy over CI in enhancing intrinsic goal orientation. These findings were further corroborated in the delayed post-test, where the CI vs. SCTM difference widened to -4.260 (p < .001), underscoring the sustained effectiveness of SCTM. The comparisons between CI vs. CAM and CAM vs. SCTM were less consistent, indicating variable effects across test phases.

4.5. Effect of instructional strategies on "extrinsic goal orientation"

This section discusses how different instructional methods influence students' extrinsic goal orientation. The results highlight the varying degrees of impact of these strategies, with particular attention paid to the notable effectiveness of the SCTM model, as detailed in the subsequent analysis.

Table 8. Summary of ANCOVA and post-hoc results for extrinsic goal orientation.

Test Phase	Source	F Value	p-value	Comparison	Mean Diff.	p-value	95% CI Lower	95% CI Upper
Post-Test	Model	4.875	.009	CI vs SCTM	-2.557	.002	-4.177	-0.937
				CI vs CAM	-1.359	.098	-2.973	0.254
				CAM vs SCTM	-1.198	.146	-2.817	0.421
Delayed Post-Test	Model	5.004	.008	CI vs SCTM	-2.522	.002	-4.098	-0.946
				CI vs CAM	-1.262	.114	-2.835	0.311
				CAM vs SCTM	-1.260	.116	-2.836	0.316

From **Table 8**, The ANCOVA demonstrated that instructional strategies had a significant impact on extrinsic goal orientation, as shown by the results from both the post-test and delayed post-test phases. Specifically, the SCTM strategy was notably effective, as evidenced by the significant differences observed in the post-test and sustained in the delayed post-test compared with the CI strategy (post-test: -2.557, p = .002; delayed post-test: -2.522, p = .002). These results underscore the effectiveness of the SCTM strategy in enhancing students' extrinsic goal orientation, suggesting that it is a potent tool for motivating students in educational settings. Comparisons involving CAM did not reach statistical significance, indicating more nuanced effects, which may require further exploration.

4.6. Effect of instructional strategies on "task value" of motivation

This section examines the effects of various instructional strategies on students' perceived task value, which is an essential component in fostering engagement and motivation. The findings illuminate how different teaching methods impact the value that students assign to their learning tasks over time.

Table 9. Summary of ANCOVA results and post-hoc comparisons for task value of motivation.

Test Phase	Source	F Value	p-value	Comparison	Mean Diff.	p-value	95% CI Lower	95% CI Upper
Post-Test	Model	7.656	.000	CI vs SCTM	-2.315	.003	-3.814	-0.816
				CI vs CAM	-0.286	.708	-1.781	1.209
				CAM vs SCTM	-2.029	.009	-3.528	-0.530
Delayed Post-Test	Model	14.047	.000	CI vs SCTM	-4.611	< .001	-6.320	-2.902
				CI vs CAM	-2.478	.005	-4.184	-0.772
				CAM vs SCTM	-2.133	.015	-3.842	-0.424

From **Table 9**, the analysis of covariance (ANCOVA) assessed the impact of instructional strategies on the task value of motivation, showing significant results both immediately and over time. The SCTM strategy did much better than the CI strategy at improving task value, with a mean difference of -2.315 (p =.003) on the post-test and -4.611 (p <.001) on the delayed post-test. These results underscore the efficacy of the SCTM strategy in significantly enhancing the perceived value of tasks among students, suggesting its potential for fostering deeper engagement and motivation in educational contexts. Comparisons involving CI and CAM indicated less consistent effects, highlighting the specific strengths of SCTM in motivating students.

4.7. Effect of instructional strategies on "control of learning beliefs"

Exploring the influence of instructional strategies on students' control of learning beliefs, this section presents a detailed analysis of how these strategies help shape their perceptions of their learning environments and their ability to control their educational outcomes. The discussion below focuses on the comparative effectiveness of each strategy in the different testing phases.

Table 10. Summary of ANCOVA results and post-hoc comparisons for control of learning beliefs.

Test Phase	Source	F Value	p-value	Comparison	Mean Diff.	p-value	95% CI Lower	95% CI Upper
Post-Test	Model	19.791	< .001	CI vs SCTM	-3.980	< .001	-5.447	-2.513
				CI vs CAM	-2.778	.001	-4.245	-1.311
				CAM vs SCTM	-1.202	.044	-2.669	-0.735
Delayed Post-Test	Model	14.813	< .001	CI vs SCTM	-3.900	< .001	-5.344	-2.456
				CI vs CAM	-2.540	.001	-3.984	-1.096
				CAM vs SCTM	-1.360	.033	-2.804	-0.916

From **Table 10**, analysis of covariance (ANCOVA) was employed to assess the impact of different instructional strategies on students' control of learning beliefs, which revealed significant effects in both post-test and delayed assessments. In particular, the SCTM strategy substantially improved students' control over their learning beliefs, significantly outperforming both CAM and CI strategies. There was a mean difference of -3.980 between SCTM and CI on the post-test (p <.001), and this effect lasted on the delayed post-test with a difference of -3.900 (p <.001).These results suggest that SCTM not only immediately enhances, but also durably impacts students' learning beliefs, advocating its broader implementation in educational settings to foster robust learning environments.

In a comprehensive analysis of the impact of teaching strategies on mathematical learning motivation across various motivational constructs, SCTM teaching methods emerged as the most effective strategy, significantly outperforming other approaches like conventional teaching methods (CI) and cognitive apprenticeship model (CAM) strategies. Specifically, SCTM demonstrated superior outcomes in fostering intrinsic goal orientation, enhancing task value, and strengthening control of learning beliefs in both immediate and delayed assessments. CI consistently needs to catch up with other strategies, particularly in promoting extrinsic goal orientation and sustaining task value over time. These findings underscore the potential of SCTM to robustly enhance diverse aspects of learning motivation, suggesting that its strategic implementation could yield substantial educational benefits. This study highlights the necessity of tailoring teaching approaches to optimize learning motivation, considering the broader educational context and the specific needs of learners.

5. Discussion

This study examined the effectiveness of a Stratified Cognitive Apprenticeship Model Teaching Module (SCTM) compared to conventional instruction (CI) and cooperative autonomous mastery (CAM) in enhancing mathematical learning motivation. The findings demonstrate that SCTM significantly improved intrinsic goal orientation and task value, outperforming CI and CAM. This supports earlier research suggesting that tailored, stratified teaching can profoundly impact students' self-confidence and, thereby, their motivation to learn[43]. Differentiated instruction positively impacts the academic self-concept of secondary school students and their overall self-concept in school[20]. Stratified teaching differentially affects students' self-confidence, which is crucial for motivating learning[42]. Meanwhile, CAM promotes active participation, which is conducive to knowledge construction and boosts achievement and self-efficacy[2,9]. Additionally, CAM's emphasis on expert guidance and collaboration augments student autonomy and makes learning more engaging[31].

In classrooms applying SCTM, teachers segment students into distinct groups based on their prior knowledge and learning capabilities, tailoring learning objectives and tasks accordingly. This stratification allows students to engage with content that matches their skill level, from tackling complex problems to grasping fundamental concepts and facilitating an optimal learning environment through peer interactions. Within this framework, teachers function as mentors, foster a cooperative learning climate, and enhance students' perceptions of mathematical values and self-confidence through successful learning experiences and constructive feedback. This approach boosters students' comprehension of the subject matter and positively impacts their overall motivation to learn, as evidenced by enhanced elevated motivational indices.

The emphasis on active student participation and autonomy within CAM, as noted by Collins et al.[2] and Lave and Wenger[11], aligns with our findings that SCTM enhances these aspects more effectively by integrating systematic expert guidance and peer collaboration.

In summary, the SCTM's capacity to accommodate a wide range of learning needs while fostering profound comprehension and motivation renders it a superior instructional strategy compared to standard CI methods. Although CAM is helpful in promoting student autonomy and engagement, SCTM enhances these benefits by offering a controlled yet adaptable learning environment well-suited to students' cognitive growth. Recent educational research emphasizes the significance of combining theory and practice, promoting active learning, and offering customized training that caters to individual learning requirements[18].

Thus, the integration of stratified instruction and cognitive apprenticeship principles in SCTM provides a holistic approach to improving learning motivation in mathematics education.

6. Implications and future directions

6.1. Teaching implications

The implications for teaching are profound. Xu et al.[33] emphasized the value of collaborative problem solving in enhancing critical thinking skills, a notion that aligns with our findings on the effectiveness of SCTM. In high school mathematics, combining differentiated instruction with the Cognitive Apprenticeship Model (CAM) within the scaffolded Cognitive Apprenticeship Teaching Module (SCTM) significantly improved students' learning motivation.

The Cognitive Apprenticeship Model (CAM), which focuses on learning in a social context and utilizes interactive methods, enhances the frequency and quality of student interaction and collaborative learning[1]. The SCTM module provides a structured approach that allows teachers to tailor instruction according to individual student needs. Coupled with a teacher-supported learning framework, this ensures that each student receives appropriate guidance, making learning more meaningful and effective, thereby promoting an increase in learning motivation.

6.2. Learning implications

For learning, the use of CAM has shown improvement in mathematical overall student motivation[18,23]. This underscores the necessity for high school mathematics teachers to adopt innovative and differentiated instructional strategies that cater to individual students' needs. Using the Stratified Cognitive Apprenticeship Teaching Module (SCTM) in this study has shown significant promise in enhancing students' learning motivation. This curriculum deviates from conventional, inactive teaching approaches by promoting an energetic, captivating learning atmosphere. The SCTM customizes educational experiences to cater to the different needs of students in mathematics by incorporating digital technologies and implementing stratified teaching methods, resulting in meaningful and contextually relevant learning.

6.3. Educational management implications

From an educational management perspective, this study advocates strategic training for educators in diverse instructional strategies to effectively meet various student needs[7]. Educational administrators should foster a flexible teaching environment that supports innovative teaching methods and situational adjustments tailored to student needs[4]. By providing educators with varied teaching strategies, administrators can boost student motivation through personalized and adaptive methods that cater to individual learning preferences.

6.4. Theoretical implications

Theoretically, this study enriches the Cognitive Apprenticeship Model by integrating it with stratified teaching approaches, thereby providing a comprehensive framework that enhances both teaching efficacy and student-learning outcomes.

In conclusion, this study validates SCTM as a superior method for fostering mathematical learning motivation among high school students. These findings not only support but also extend the theoretical foundations of the Cognitive Apprenticeship Model and stratified instruction, thereby providing a potent strategy for educational practice and research.

Conflict of interest

The authors declare no conflict of interest.

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Appendix

Motivation for Learning Questionnaire

Class:

Gender:

Age:

Learning Motivation

The following questions were asked about your motivation and attitudes regarding the math class. Recall that there are no right or wrong answers, just answers as accurately as possible. The scale below was used to answer these questions: if you think the statement is very true, mark 7; if a statement is not at all true, mark 1. If the statement is more or less true, find the number between one and seven that best describes you.

Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
1	2	3	4	5	6	7

Subscale	Questions	Score
Intrinsic goal orientation	In my math class, I prefer course material that really challenges me so I can learn new things.	
	In my math class, I prefer course material that arouses my curiosity, even if it is difficult to learn.	
	The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.	
	When I have the opportunity in my math class, I choose course assignments that I can learn from even if they don't guarantee a good grade.	
Extrinsic goal orientation	Getting a good grade in math is the most satisfying thing for me right now.	
	The most important thing for me right now is improving my overall math grade point average, so my main concern in math class is getting a good grade.	
	If I can, I want to get better grades in math class than most of the other students.	
	I want to do well in math class because it is important to show my ability to my family, friends, employer, or others.	
Task Value	I think I will be able to use what I learn in math course in other courses.	
	It is important for me to learn the course material in math class.	
	I am very interested in the content area of math course.	
	I think the course material in math class is useful for me to learn.	
	I like the subject matter of math course.	
	Understanding the subject matter of math course is very important to me.	
Control of learning beliefs	If I study in appropriate ways, then I will be able to learn the material in math course.	
	It is my own fault if I don't learn the material in math course.	
	If I try hard enough, then I will understand the course material.	
	If I don't understand the course material, it is because I didn't try hard enough.	