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The Impact of Integrating the Flipped Classroom Strategy with Think-Aloud Techniques in Mathematics Instruction on Enhancing Deep Understanding and Self-Efficacy Among Female University Students

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Abstract

This study aimed to examine the impact of integrating the flipped classroom strategy and think-aloud strategy on developing deep understanding and self-efficacy in mathematics among preparatory-year female students in Saudi Arabia. A quasi-experimental design was employed with a sample of 80 students enrolled in a general mathematics course. Participants were randomly assigned to two equivalent groups: the experimental group (40 students), who studied the course using the integrated flipped classroom and think-aloud strategies, and the control group (40 students), who studied the same course using traditional methods. The study utilized a deep understanding test in mathematics and a self-efficacy scale in mathematics as data collection instruments. Both instruments were administered to the two groups before and after the treatment, and the collected data were analyzed statistically. The results revealed a statistically significant difference in favor of the experimental group in the post-test scores of both the deep understanding test and the self-efficacy scale, indicating a high effect size and strong effectiveness. The study recommended that university faculty members adopt modern teaching strategies, particularly those integrating multiple instructional approaches such as the flipped classroom and think-aloud strategies. It also emphasized the importance of training faculty members on these methods to enhance various aspects of teaching and learning at the university level.

Keywords: *Flipped Classroom, Think-Aloud Strategy, Deep Understanding, Self-Efficacy, Preparatory Year, Female Students.*

Introduction

Educational systems worldwide strive to enhance their teaching methods to keep pace with rapid advancements in educational technology. Technological tools have become integral to daily life, shaping individuals' understanding of the world and serving as a means for continuous knowledge and skill development. These tools have significantly influenced learners' cognitive processes, accelerating their acquisition of knowledge and skills. Consequently, educational systems have increasingly adopted various technological tools to improve learning outcomes.

Despite the integration of technology in universities, traditional teaching methods that emphasize rote memorization and knowledge accumulation remain prevalent. These methods

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have been criticized for their limited effectiveness in ensuring long-term retention of skills and knowledge. Many educators argue that relying solely on traditional instruction does not equip students with the necessary competencies for lifelong learning. Arum and Roksa (2011) emphasized the need for alternative instructional approaches that align with the rapid expansion of knowledge across disciplines, preparing students for real-world applications post-graduation.

As a result, many researchers have explored teaching strategies that incorporate technological advancements to promote active and constructive learning. Modern educational approaches focus on engaging students in their learning process, encouraging knowledge exploration and discovery. In mathematics education, researchers have developed innovative teaching methods that integrate technology into instruction, either fully or partially. Examples include e-learning, blended learning, and the flipped classroom strategy (Alshammari, 2023).

The flipped classroom is a modern instructional approach that addresses the limitations of traditional learning while fostering students' cognitive skills. This strategy combines elements of both traditional teaching and active learning (Bishop & Verleger, 2013). It shifts the learning process by allowing students greater control over their pace of study and enabling them to review instructional materials as needed. In the classroom, the approach promotes student interaction, collaboration, and critical thinking, providing educators with more opportunities to engage directly with students rather than delivering lessons (Hussain et al., 2023; Sun & Xie, 2020).

Implementing the flipped classroom has demonstrated several benefits, including the development of higher-order thinking skills (Lee & Lai, 2017), enhanced student engagement and satisfaction (Fisher et al., 2021), and increased collaboration and discussion among students (Lauvas & Styve, 2018). Additionally, research suggests that this approach reduces mathematics anxiety, improves academic achievement, fosters a positive attitude toward learning mathematics, and enhances self-directed learning and mathematical reasoning (Alhamdani & Albreiki, 2018; Dove & Dove, 2014; Hwang & Lai, 2017; Pierce, 2013; Sun et al., 2018).

Educators and curriculum developers continuously seek effective teaching strategies that create positive learning environments, strengthen social connections within the classroom, and encourage students to exchange ideas, opinions, and experiences. These strategies aim to stimulate creative thinking and gradually develop students' cognitive abilities, ultimately leading to mastery of essential skills (Abu Darb, 2019). One area of growing interest is metacognitive strategies, which support students in understanding learning processes, recognizing goals, and identifying the cognitive strategies required to achieve them (Al-Suwaidan & Al-Zuhairi, 2022).

One such metacognitive strategy is the think-aloud strategy, which has its roots in Vygotsky's social constructivist theory (Saadeh & Taqem, 2017). This strategy represents one of the highest levels of thinking, as it encourages individuals to reflect on their thought processes. It involves cognitive operations that help learners understand and recall content by verbalizing their thoughts, questioning concepts, and analyzing information aloud (Aledwan & Daoud, 2016). The fundamental principle of this strategy is that learners openly express their thoughts, allowing educators and peers to observe their reasoning and guide them toward more effective thinking strategies. This process facilitates the integration of prior and new knowledge, fostering deeper learning (Razouki & Abdul Kareem, 2015).

Nujaili and Alhashmi (2019) argue that the think-aloud strategy requires both the speaker and the listener to possess strong cognitive and communication skills. The strategy enables learners to articulate their ideas audibly, allowing peers and instructors to identify misconceptions and provide corrective feedback (Abu Darb, 2019). This approach enhances critical thinking, discussion skills, and self-reflection while fostering a collaborative learning environment (Alamodi, 2011).

Research has demonstrated the effectiveness of the think-aloud strategy as a powerful learning tool (Merchie & Keer, 2014; Nakakoji & Wilson, 2020; Wolcott & Lobczowski, 2021) and a key factor in self-regulated learning (Altalhi et al., 2021; Whitehead et al., 2018). Additionally, it has been identified as one of the best methods for gathering data on students' self-regulated learning experiences (Bai, 2018).

At the university level, equipping students with 21st-century skills is essential for fostering creativity and knowledge production. Higher education institutions must shift from a content-heavy, memorization-based approach to one that emphasizes knowledge analysis, synthesis, and application. This shift necessitates the adoption of more effective instructional strategies that cultivate critical thinking, creativity, deep understanding, and self-efficacy (Al-Barami, 2023).

Self-efficacy in mathematics is a critical affective variable that significantly influences students' cognitive and skill development. Hanin and Nieuwenhoven (2016) highlighted the substantial impact of self-efficacy on students' academic performance, their perception of mathematics' relevance in daily life, and their motivation to learn the subject. Research has shown that students with high self-efficacy demonstrate greater engagement, persistence, and ambition in problem-solving tasks compared to those with lower self-efficacy (Amri & Widada, 2019; Clemente et al., 2024; Kohen et al., 2019; Zamnah, 2019).

Based on these insights, this study aims to investigate the impact of integrating the flipped classroom and think-aloud strategies on the development of deep understanding and self-efficacy in mathematics among preparatory-year female students at Imam Abdulrahman Bin Faisal University in Saudi Arabia.

Research Problem and Questions

The first year of university, often referred to as the preparatory year, is a unique experience for new students. It represents a transition into a new educational environment that differs significantly from high school, evoking feelings of ambition and uncertainty, hesitation and enthusiasm, as well as fears and hopes. The primary objective of the preparatory year is to prepare students for university life in all its aspects. Aloqaili (2014) emphasized the pivotal role of the first year in equipping students with the academic, social, psychological, and practical skills necessary for success in university studies.

Mathematics is one of the most important courses offered in the preparatory year, serving as a foundation for many scientific disciplines and a prerequisite for future studies. Despite its significance, many students face considerable challenges in learning mathematics during the preparatory year. Several studies (e.g., Al-Daweesh, 2019; Al-Sharif et al., 2019; Al-Zoubi et al., 2019; El-Refai, 2020;) have highlighted these difficulties. Al- Daweesh (2019) pointed out that instructional methods often fail to accommodate individual differences among learners. Al-Sharif et al. (2019) identified students' struggles in transitioning from general education to university-level mathematics. High failure and dropout rates in university mathematics courses, low academic performance, and heightened levels of math anxiety negatively impact students' self-efficacy and mathematical knowledge. Al-Zoubi et al. (2019) found that university students, particularly in their first year, exhibit low self-efficacy and struggle to apply learned thinking skills, as traditional lectures remain the dominant teaching method. Similarly, El-Refai (2020) confirmed the decline in self-efficacy among preparatory-year students. Khalil (2020) observed that lecture-based teaching leads to student disengagement, while heavy course content and insufficient study time further exacerbate the issue.

Al-Zebidi (2021) reported that a significant number of first-year university students avoid disciplines that require mathematics courses. Alsubaie and Alshahrani (2023) further noted that preparatory-year students face multiple challenges in learning mathematics, with many struggling to adapt to the university environment. Additionally, university faculty members often find it difficult to design and develop learning environments that support deep and active learning strategies (McLean et al., 2016).

The researchers of this study, based on their experience in teaching university-level preparatory mathematics and their analysis of students' results in general mathematics exams, observed that 70% of students fail to answer questions requiring deep conceptual understanding, while nearly 90% perform well on questions assessing lower-order cognitive skills, such as memorization and recall. Faculty members have also reported that students demonstrate weaknesses in deep understanding and self-efficacy in mathematics.

Given these findings, this study seeks to examine the integration of the flipped classroom and think-aloud strategies to assess their impact on enhancing deep understanding and self-efficacy in mathematics.

Accordingly, the research problem is defined by the following main question:

What is the effect of integrating the flipped classroom and think-aloud strategies in teaching general mathematics on developing deep understanding and self-efficacy in mathematics among female preparatory-year students?

To address this main question, the study explores the following sub-questions:

1. What is the effect of integrating the flipped classroom and think-aloud strategies in teaching general mathematics on developing deep understanding among female preparatory-year students?

2. What is the effect of integrating the flipped classroom and think-aloud strategies in teaching general mathematics on developing self-efficacy in mathematics among female preparatory-year students?

Research Hypotheses

To answer the research questions, the following two hypotheses were formulated:

1. There is a statistically significant difference between the mean scores of students in the experimental group and those in the control group in the post-test of deep understanding in general mathematics, favoring the experimental group. This difference is attributed to the teaching strategy.

2. There is a statistically significant difference between the mean scores of students in the experimental group and those in the control group in the post-test of self-efficacy in mathematics, favoring the experimental group. This difference is attributed to the teaching strategy.

Research Aim

This study aims to explore the effect of integrating the flipped classroom and think-aloud strategies in teaching general mathematics on developing deep understanding and self-efficacy in mathematics among female preparatory-year students.

Research Significance

This study is significant because:

1. It aligns with modern educational trends that emphasize experimenting with and evaluating the effectiveness of innovative teaching strategies in mathematics education.

2. It provides effective teaching strategies for higher education that enhance deep understanding and self-efficacy in mathematics.

3. It highlights the importance of integrating different teaching strategies and measuring their effectiveness.

Theoretical Framework & Literature Review

Flipped Classroom Strategy

The flipped classroom strategy is one of the most significant teaching strategies introduced into the educational field. The rapid advancement and widespread adoption of technology have facilitated its development, enabling educators to explore new ways to integrate digital tools into teaching and learning. Traditional lecture-based instruction has become less preferred, making innovative strategies like the flipped classroom increasingly relevant (Namaziandost et al., 2020).

The flipped classroom is grounded in several educational theories. Piaget's cognitive constructivist theory emphasizes active and meaningful learning, where students engage with instructional materials and practice scientific thinking—key aspects of the flipped classroom. Vygotsky's social constructivist theory highlights the role of teachers, peers, and parents as mediators in learning. The flipped model also aligns with connectivist learning theory, which is particularly suited to the digital era, as it enables students to engage with instructors through digital communication tools such as social media and educational websites, facilitating fast and easy knowledge exchange (Ng, 2015).

In a flipped classroom, instructional content is delivered to students outside the classroom through online resources such as videos (Burke & Fedorek, 2017). This approach allows students to participate in active learning activities during class time, including discussions, problem-solving, and collaborative work (Findlay-Thompson & Mombourquette, 2014; Sengel, 2016). Class time is dedicated to interactive learning, reinforcing the concepts students encountered in pre-recorded videos (La Marca & Longo, 2017). The flexibility of this approach enables students to learn at their own pace, pausing, rewinding, or fast-forwarding instructional videos without time or location constraints (Chuang et al., 2018; Moos & Bonde, 2016; Sun et al., 2017). Furthermore, students can focus on their learning needs without redundancy, and teachers can identify and address students' misconceptions through in-class activities (Davies et al., 2013).

In a flipped classroom, teachers assume multiple roles beyond traditional instruction. They act as subject matter experts, instructional designers, and multimedia developers (Shih & Tsai, 2017). Brewer and Movahedazarhouligh (2019) describe the flipped classroom as an instructional approach that shifts direct instruction from a group learning space to an individual learning space, transforming the classroom into a dynamic, interactive environment where teachers guide students in applying concepts and skills. The flipped model is implemented in two formats:

i. Partial flipping, where only a portion of the content is delivered through the strategy.

ii. Full flipping, where the entire instructional content is delivered using the flipped approach.

Clark (2015) outlines a six-step process for implementing the flipped classroom strategy. The process begins with selection, where educators identify lessons or skills best suited for the flipped model. This is followed by analysis, which involves examining the content to determine key knowledge, concepts, and skills. In the design phase, teachers create interactive instructional videos incorporating audio and visual elements. The guidance step requires students to watch the assigned video on an educational platform before class. During application, students engage in hands-on activities to apply the concepts learned. Finally, assessment is conducted using appropriate evaluation tools to measure student learning during class.

The flipped classroom model offers numerous benefits that enhance the learning experience by integrating technology and addressing students' diverse needs. According to Schallert and Krainer (2018), this approach provides teachers with more time to support students and address inquiries while facilitating active learning. It expands instructional options through modern technology and effectively doubles learning time by combining pre-class and in-class instruction. The model seamlessly integrates blended and synchronous/asynchronous learning, fostering critical thinking, self-directed learning, communication, and collaboration skills. Additionally, it boosts students' confidence and engagement, saving class time for interactive activities since core content is covered in pre-class videos. By shifting the teacher's role from lecturer to facilitator, it transforms students from passive recipients of information into active participants in the learning process. Teachers can also quickly assess students' progress through in-class interactions and performance, helping them develop higher-order thinking skills. Moreover, the model aligns with the demands of the digital age, catering to a generation accustomed to using technological tools in their daily lives.

The flipped classroom strategy responds to the evolving educational landscape by integrating technology into learning, making instruction more engaging, student-centered, and effective.

Think-Aloud Strategy

The think-aloud strategy is a metacognitive approach where individuals articulate their thoughts while engaging with a topic or problem. This strategy makes the learner's cognitive processes visible during problem-solving and reflection. It involves self-analysis to identify the mental operations performed, including planning, decision-making, and strategy selection. Teachers use this method to observe students' thinking skills and provide feedback when they detect incomplete or incorrect reasoning (Atiyah, 2016).

Learners are encouraged to verbalize their thoughts while reading a text or solving a scientific problem. This strategy clarifies how students arrive at solutions or respond to questions, guiding them through problem identification, understanding, data analysis, execution, and interpretation (Hamouda, 2013).

The think-aloud strategy relies on teacher-led questioning, with the type of questions depending on instructional goals. Some questions aim to review and confirm understanding, requiring a simple question-and-answer format. Others aim to develop thinking skills by using problem-based discussions to stimulate students' motivation. Teachers help students become aware of their thought processes, guide them in monitoring their strategies, and teach them how to evaluate their effectiveness. If the goal is to share experiences, discussions should be interactive, allowing students to develop independent thinking and express their opinions through dialogue. Engaging in shared discussions refines and expands their ideas (Babatain, 2015).

Sonmez and Sulak (2018) classify the think-aloud strategy into two categories:

i. Teacher Think-Aloud: Since students learn best by observing strong models, teachers verbalize their thoughts to highlight key points for students who struggle with comprehension. By demonstrating their own thinking process, teachers help students understand how to use the strategy effectively.

ii. Student Think-Aloud: In this approach, teachers pose questions that prompt students to think aloud in small groups or pairs. Students take turns verbalizing their thought process while others listen and record key ideas. This ensures equal opportunities for all students to practice the strategy, either in pairs or individually (Raihan, 2011).

Hartman (2001) outlines key steps for implementing the think-aloud strategy, emphasizing the importance of verbalizing thoughts and reasoning throughout the learning process. This begins with converting all thoughts and mental images into clear, understandable words that others can hear. Students should articulate every step of their thinking process while solving problems or completing tasks, expressing preliminary thoughts before taking action. This includes planning questions such as identifying objectives, determining the best approach, and considering the rationale behind their choices. Throughout the task, students must continuously verbalize their ideas and reasoning, reflecting on each step before and during problem-solving.

The think-aloud strategy offers numerous advantages that enhance learning and cognitive development. Wilhelm (2001) highlights that it improves knowledge retention, higher-order thinking skills, and motivation for future learning. By fostering collaborative learning, students can freely discuss ideas without feeling overwhelmed, promoting active engagement and a positive attitude toward intellectual inquiry. The strategy encourages students to generate questions, gather information, and develop intrinsic motivation while providing continuous feedback from teachers and peers, prompting reassessment of their reasoning. It also enhances problem-solving skills by exposing students to diverse perspectives and encouraging structured thinking, allowing them to articulate hypotheses, inferences, classifications, and arguments. By reducing passive learning and rote memorization, the think-aloud approach fosters deeper understanding within authentic learning contexts. Additionally, it strengthens cognitive growth by integrating intellectual and social aspects of learning, encouraging student participation while enabling teachers to provide ongoing guidance. Finally, it develops decision-making, judgment, and reasoning skills by helping students recognize cause-and-effect relationships, making learning more meaningful and reflective.

Deep Understanding

Fenwick et al. (2014) defines deep understanding as the ability to provide multiple explanations for a problem or topic and develop new, innovative solutions. Bitter and Loney, (2015) describes it as a form of learning where the learner takes responsibility for their own learning, integrating new knowledge into their memory to create lifelong, sustainable learning that retains its impact and applicability. Friesen and Scott (2013) define deep understanding as the learner's ability to offer in-depth explanations of a subject by posing questions, reviewing knowledge, constructing ideas, and solving problems. King (2016) describes it as students' ability to ask questions, clarify, and explain beyond mere facts, demonstrating persistence in understanding the subject and achieving advanced levels of comprehension.

In mathematics, deep understanding emerges from the connections learners make between new information and their existing knowledge structure. These connections help in developing logical and reasonable solutions to mathematical problems using key concepts (Zanqour, 2018).

McConnell et al. (2013), and Fenwick et al. (2014) outline several key skills associated with deep understanding:

1. Generative Thinking: Includes fluency in generating meanings and ideas, flexibility in thinking, hypothesis formation, and making predictions based on given data.

2. Decision-Making: The ability to make appropriate decisions when faced with a situation, with justification for the choice made.

3. Interpretation Skills: The ability to explain learning experiences and provide logical meaning to results or relationships, drawing on prior knowledge or the nature and characteristics of the mathematical problem.

4. Questioning: The ability to ask a wide range of questions, including those related to recall, comprehension, application, analysis, and beyond.

Deep understanding offers significant benefits, as outlined by Salehudin and Alpert (2022). It enhances cognitive effort by engaging a network of interconnected learning elements and supports essential skills such as decision-making, problem-solving, research, and evaluation. By focusing on meaningful cognitive patterns, it ensures that acquired knowledge is more interconnected, memorable, and applicable across multiple contexts. Furthermore, it strengthens the ability to link causes and effects, requiring learners to engage in planning, discovery, monitoring, and control processes to better understand relationships between strategies, processes, and outcomes. By connecting new knowledge with prior knowledge within a conceptual framework, deep understanding fosters structured thinking, enabling comparison, differentiation, and the comprehension of opposing ideas, all of which contribute to meaningful learning. It also helps develop an organized understanding of concepts, principles, and procedures, ultimately promoting lifelong learning through authentic learning experiences.

Tam (2022) identifies several factors that influence deep understanding, including thought-provoking questioning, linking prior knowledge with new knowledge, employing modern learning strategies, diversifying classroom and extracurricular activities, practicing authentic assessment methods, and integrating thinking skills into the learning process.

Mathematical Self-Efficacy

Mathematical self-efficacy is a key factor emphasized by the National Council of Teachers of Mathematics (NCTM) as essential for student development in the affective domain of mathematics learning. It plays a crucial role in ensuring students' persistence in completing mathematical tasks (Ebada, 2018). It reflects a learner's judgments, expectations, and beliefs about their ability to understand new mathematical concepts, solve problems, acquire mathematical knowledge, master skills, and integrate new information with prior knowledge, ultimately shaping their learning behavior (Hussein, 2019).

Extensive research has been conducted on students' self-efficacy, with studies showing a strong correlation between self-efficacy and mathematics performance (Roick & Ringeisen, 2018; Skaalvik et al., 2015; Zakariya, 2021). Additionally, research by Ayotola and Adedeji (2009), Motlagh et al. (2011), and Simamora et al. (2018) indicates that student motivation can be strongly predicted by self-efficacy. Therefore, educators must take students' self-efficacy seriously and implement strategies to enhance their mathematical learning. Designing effective learning experiences that reinforce students' confidence in their abilities is essential.

Bandura's Self-Efficacy Theory identifies four key sources that influence self-efficacy: performance accomplishments, vicarious experiences, verbal persuasion, and emotional arousal (see Figure 1). Each of these sources directly impacts self-efficacy and plays a mediating role in shaping behavior. They serve as valuable targets for interventions aimed at developing or modifying self-efficacy beliefs, ultimately enabling individuals to achieve specific goals (Gao, 2019; Lippke, 2020).

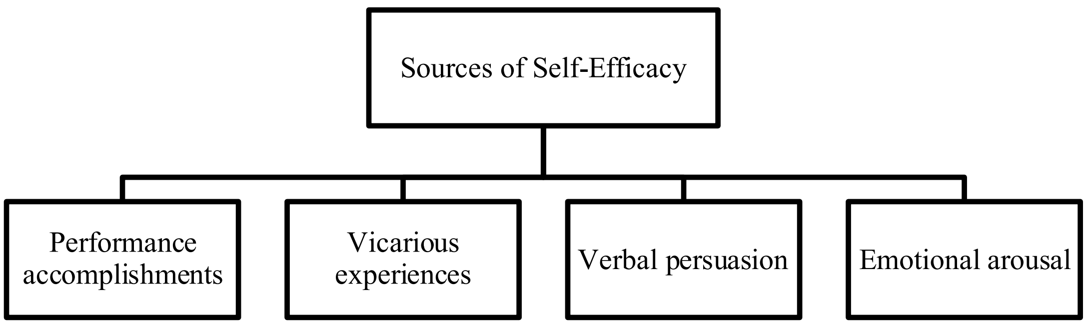

Figure 1.

Sources of Self-Efficacy in Bandura's self-efficacy theory

Methodology

The current study employed a quasi-experimental design to examine the impact of the independent variable—the integration of the flipped classroom and think-aloud strategies—on two dependent variables: deep understanding and self-efficacy in mathematics among a group of preparatory-year female students.

To ensure equivalency between groups, the study utilized a matched-groups design, selecting two groups: an experimental group consisting of 40 students and a control group consisting of 40 students. Participants were randomly assigned to these groups (see Table 1). The experimental group was taught a general mathematics course using the integrated approach of the flipped classroom and think-aloud strategies, while the control group received instruction using traditional teaching methods. Pre- and post-tests were administered to both groups using the study's instruments (Deep Understanding Test and Mathematics Self-Efficacy Scale).

Groups	Pretest	Treatment	Post-test
Experimental	O_1	X	O_2
Control	O_1	-	O_2

Table 1: Quasi-Experimental Research Design

Research Sample

A random sampling method was used to select 80 first-year preparatory female students enrolled in the General Mathematics course at Imam Abdulrahman Bin Faisal University, Saudi Arabia, during the second semester of the 2024/2025 academic year.

Instrumentation

A. Deep understanding skills test:

Based on a review of relevant literature and previous studies, along with an analysis of the General Mathematics course content for first-year preparatory students, the Deep Understanding Skills Test was developed following these steps:

i. Defining the test objective: The test aimed to assess female students' levels of deep understanding skills in General Mathematics.

ii. Identifying the dimensions of deep understanding: The test was designed to measure specific deep understanding skills, including generative thinking skills (mathematical fluency, mathematical flexibility, hypothesis formulation, and prediction based on given data), deep questioning, deep mathematical interpretation, and mathematical decision-making.

iii. Developing the initial test version: A test specification table was created, followed by the development of the initial test version.

Test validity. The face validity of the test was assessed by presenting the initial version to four experts specializing in mathematics, each with over ten years of teaching experience. The experts provided feedback, suggesting modifications to the structure of the main problems. All recommended revisions were implemented.

After incorporating the modifications, the revised version of the Deep Understanding Skills Test was piloted with a sample of 38 first-year preparatory students who were not part of the main study sample. This pilot study aimed to assess the test’s reliability, item difficulty and ease indices, item discrimination indices, and the estimated time required to complete the test.

Test reliability. Cronbach’s alpha coefficient was used to determine the reliability of the test using SPSS software (see Table 2).

Domains		Coefficient
Generative thinking skills	mathematical fluency	0.75
	mathematical flexibility	0.79
	hypothesis formulation	0.82
	prediction based on given data	0.86
Deep questioning		0.84
Deep mathematical interpretation		0.72
Mathematical decision-making		0.81

Whole	0.80

Table 2: Reliability Coefficient for the Deep Understanding Skills Test

Table 2 shows that the reliability coefficients range from 0.72 to 0.86, indicating a high level of reliability for the Deep Understanding Skills Test.

Item discrimination ability. After administering the test to a pilot sample of 38 students, Pearson correlation coefficients were calculated between each subskill score and the total test score (see Table 3).

Domains		Correlation Coefficient
Generative thinking skills	mathematical fluency	0.832**
	mathematical flexibility	0.638**
	hypothesis formulation	0.765**
	prediction based on given data	0.714**
Deep questioning		0.836**
Deep mathematical interpretation		0.698**
Mathematical decision-making		0.805**

Table 3: Correlation Coefficients for the Deep Understanding Skills Test

Note. ** significant at 0.01 level.

Table 3 shows that the correlation coefficients between each subscale and the overall test score are statistically significant at the 0.01 level. This indicates a high level of item discrimination within the test.

Item difficulty and discrimination indices. The difficulty indices for the test items were calculated, ranging between 0.24 to 0.77. The discrimination indices were also computed based on item difficulty values, ranging between 0.21 and 0.25.

The estimated test duration was determined by calculating the average time each student in the pilot study took to complete all questions. The average test duration was approximately 90 minutes.

After incorporating the suggested revisions from expert reviewers and verifying the validity and reliability of the test, the final version was structured with 30 items, with a total score of 50 points.

B. Mathematical self-efficacy scale:

Based on a review of relevant educational literature and prior studies on self-efficacy in mathematics (Melhem & Al-Jarah, 2024; Rakhmi et al., 2018; Zulkarnain et al., 2021), a mathematical self-efficacy scale was developed. The scale aimed to assess the level of self-efficacy in mathematics among preparatory-year female students at Imam Abdulrahman Bin Faisal University.

The scale consisted of three domains: (1) mathematical language and its use, (2) mathematical reasoning in problem-solving, and (3) solving mathematical tasks. The initial version of the scale included 23 items and was structured using a three-point Likert scale (Always, Sometimes, Rarely). Positive statements were scored as 3, 2, and 1, while negative statements were scored as 1, 2, and 3.

Scale validity. Face validity was assessed by presenting the scale to a panel of six experts specializing in curriculum, instructional methods, and educational psychology. Their feedback was incorporated, leading to the removal of some items and the revision of others.

Scale reliability. After modifications were made, the scale was administered to a pilot sample of 38 students outside the main study sample. Cronbach's alpha coefficient was calculated using SPSS to determine the reliability of the scale (see Table 4).

Domains	Coefficient
Mathematical language and its use	0.821
Mathematical reasoning in problem-solving	0.725
Solving mathematical tasks	0.783
Whole	0.784

Table 4: Cronbach's Alpha Reliability Coefficients for the Mathematical Self-Efficacy Scale

Table 4 shows that the reliability coefficients for the scale's subdimensions are high, ranging from 0.725 to 0.821. The overall reliability coefficient for the scale is 0.784, indicating an acceptable level of reliability for the mathematical self-efficacy scale.

Item discrimination ability. After administering the scale to a pilot sample of 38 students outside the main study sample, Pearson correlation coefficients were calculated between each subscale score and the overall scale score (see Table 5).

Domains	Correlation Coefficient
Mathematical language and its use	0.85**
Mathematical reasoning in problem-solving	0.83**
Solving mathematical tasks	0.78**

Table 5: Pearson Correlation Coefficients for the Mathematical Self-Efficacy Scale

Note. ** significant at 0.01 level.

Table 5 shows that the correlation coefficients between the three subdimensions of the mathematical self-efficacy scale and the overall scale score range from 0.78 to 0.85. These correlations are statistically significant at the 0.01 level, indicating that the scale items have a high discriminatory ability.

The average time required to complete the scale was determined by calculating the time taken by each student in the pilot study to respond to all scale items. The estimated completion time for the scale is 35 minutes.

Following the revisions suggested by expert reviewers and after confirming the validity and reliability of the scale, the final version was developed, consisting of 21 items. The first subdimension includes 6 items, the second subdimension includes 6 items, and the third subdimension includes 9 items, with a total possible score of 63.

Research Procedures

A concise teacher's guide was developed to outline the instructional approach integrating the flipped classroom strategy with the think-aloud strategy, following the procedural steps proposed in the study. The guide provides an overview of both strategies, their significance, benefits, and the suggested steps for their integration in teaching general mathematics.

Instructional videos covering course topics were created and structured according to the implementation steps of the flipped classroom and think-aloud strategies. Additionally, a student activity workbook was developed, containing worksheets designed to facilitate the integration of both strategies. These worksheets include tasks aligned with the instructional approach, along with clear instructions defining students' roles and expected actions.

The teacher's guide and student workbook were reviewed by five experts specializing in curriculum development, teaching methods, and educational technology. They evaluated the content, activities, and instructional materials for scientific, linguistic, and technical accuracy. All expert recommendations were taken into account, leading to necessary revisions to the guide, instructional videos, PowerPoint presentations, and activity workbook based on their feedback.

Teaching Steps Using the Integration of the two Strategies:

The general mathematics course for preparatory-year female students (experimental group) was taught using an integrated approach that combines the flipped classroom and think-aloud strategies through the following steps:

Step 1: Planning and Designing Learning Activities & Sharing Them via Blackboard: One key principle of flipped classroom design is providing students with familiar and easily accessible technology (Kim et al., 2014). In this study, Blackboard, the learning management system provided by Imam Abdulrahman Bin Faisal University, was used by the course instructors. The instructors analyzed the course content to identify essential concepts, skills, and knowledge students need to acquire. Then, the instructors recorded a video lesson or selects relevant videos from YouTube and shares them with students through Blackboard, instructing them to watch the material well before the in-class session.

Step 2: Technology-Assisted Learning Outside the Classroom: Students accessed and downloaded the instructional videos via Blackboard as part of the flipped classroom activities. They engaged with the content at home using personal computers or mobile devices. They can revisit the videos as needed, adjusting their learning pace.

While watching the videos, students are encouraged to pause, take notes, and write down any questions they may have. These notes help facilitate deeper discussions during the in-class session. After watching the lecture, students complete an online quiz on Blackboard related to the lesson. Their results are displayed immediately upon submission. If students score poorly, they are encouraged to review the video again and retake the quiz, which allows multiple attempts to ensure a deep understanding of the lesson.

Step 3: Active Learning Inside the Classroom: During the in-class session, the instructor and students engaged in interactive learning activities that emphasize student-centered instruction. The process follows these steps:

i. Addressing Student Questions: The instructors reviewed students' notes and questions from the video, providing clarifications and feedback.

ii. Applying the Think-Aloud Strategy: The instructors presented exercises and engages students in solving problems using the think-aloud strategy, which involves the following steps:

a. Instructor Demonstration: The instructor models the strategy by thinking aloud while solving a problem, demonstrating:

(i) Reading and analyzing the problem.

(ii) Identifying key information and symbols.

(iii) Determining the appropriate solution process.

(iv) Explaining each step of the solution.

(v) Verbalizing thoughts to show that all ideas and steps are relevant.

(vi) Emphasizing that the goal is to develop logical reasoning rather than just finding the correct answer.

b. Student Participation in Think-Aloud Exercises: Students engage in guided activities and are encouraged to:

(i) Express their thoughts clearly so that their peers can hear and understand them.

(ii) Verbalize their thought process before taking action, including: What am I trying to do?, When should I do this?, How should I proceed?, Why is this the best approach?, and Is this method better than another?

(iii) Speak aloud about every idea that crosses their mind while solving the problem.

(iv) Reflect on their thought process, articulate their reasoning, and explain their decision-making steps.

c. Increasing Complexity of Activities: As students become familiar with the strategy, the instructors introduced more complex tasks, encouraging discussion and interaction among students and with the instructor.

d. Collaborative Student Modeling: The instructor may pair students to apply the strategy together, exchanging roles as thinker and listener.

e. Continuous Assessment & Feedback: The instructor monitored student performance, provides probing questions, and offers formative feedback throughout the learning process.

Results

The equivalence of the experimental and control groups was verified in the pretest of deep understanding using an independent samples t-test (see Table 6).

Domains	Experimental		Control		df	t	p
	M	SD	M	SD			
Mathematical fluency	3.80	1.27	4.01	1.31	78	0.71	0.479
Mathematical flexibility	2.18	1.06	2.50	1.14	78	1.30	0.197
Hypothesis formulation	2.85	1.11	3.14	1.26	78	1.09	0.279
Prediction based on given data	3.02	1.20	2.65	1.09	78	1.44	0.153
Deep questioning	2.73	1.01	2.43	1.04	78	1.31	0.194
Deep mathematical interpretation	2.68	1.55	2.28	1.38	78	1.22	0.226
Mathematical decision-making	2.60	1.52	2.23	1.40	78	1.13	0.261
Whole	19.89	2.16	19.32	2.32	78	1.34	0.184

Table 6 shows that all t-values were not statistically significant ($p > 0.05$), indicating no significant differences between the mean scores of the experimental and control groups in the pretest of deep understanding. This confirms that both groups were equivalent before implementing the experiment.

Similarly, the equivalence of the experimental and control groups in the pretest of mathematical self-efficacy scale was verified using an independent samples t-test (see Table 7).

Domains	Experimental		Control		df	t	p
	M	SD	M	SD			
Mathematical language and its use	10.7	1.83	11.2	2.25	78	1.09	0.279
Mathematical reasoning in problem-solving	10.86	1.79	11.22	1.82	78	0.89	0.375
Solving mathematical tasks	17.56	2.52	16.52	2.94	78	1.69	0.095
Whole	40.51	4.45	38.80	5.40	78	1.55	0.125

Table 7: T-test's Results for the Pretest of Mathematical Self-Efficacy Scale

Table 7 shows that all t-values were not statistically significant ($p > 0.05$), indicating no significant differences between the mean scores of the experimental and control groups in the pretest of mathematical self-efficacy scale. This confirms that both groups were equivalent before the experiment.

To answer the first research question: *"What is the effect of integrating the flipped classroom and think-aloud strategies in teaching general mathematics on developing deep understanding among female preparatory-year students?"*, the first hypothesis was tested: *"There is a statistically significant difference between the mean scores of students in the experimental group and those in the control group in the post-test of deep understanding in general mathematics, favoring the experimental group. This difference is attributed to the teaching strategy"* (see Table 8).

Domains	Experimental		Control		df	t	p	η^2	d
	M	SD	M	SD					
Mathematical fluency	5.89	1.15	2.85	1.13	78	11.925	0.000**	0.65	2.66
Mathematical flexibility	6.21	1.147	3.01	1.012	78	13.231	0.000**	0.69	2.96
Hypothesis formulation	3.14	0.843	1.25	0.711	78	10.839	0.000**	0.60	2.40
Prediction based on given data	4.03	0.863	1.62	0.721	78	13.554	0.000**	0.70	3.03
Deep questioning	9.84	1.233	5.27	1.751	78	13.496	0.000**	0.70	3.01
Deep mathematical interpretation	8.98	1.012	4.75	1.476	78	14.948	0.000**	0.74	.034
Mathematical	2.73	0.646	1.21	0.453	78	12.184	0.000**	0.66	2.70

decision-making									
Whole	41.05	3.044	20.65	4.027	78	25.558	0.000**	0.89	5.70

Table 8: Results of the t-Test for the Posttest of Deep Understanding

Note. ** p < 0.01.

Table 8 shows a statistically significant difference ($p < 0.01$) between the mean scores of the experimental and control groups in the posttest of deep understanding, favoring the experimental group in the overall test and across all its dimensions. Thus, the first hypothesis is accepted, which stated *"There is a statistically significant difference between the mean scores of students in the experimental group and those in the control group in the post-test of deep understanding in general mathematics, favoring the experimental group. This difference is attributed to the teaching strategy."*

Table 8 also indicates that the effect size of the independent variable (the integration of the flipped classroom and think-aloud strategies) on the dependent variable (deep understanding) is large, with Cohen's d = 5.7. This value suggests a very strong effect and a high level of effectiveness in enhancing deep understanding through this integrated teaching approach.

To address the second research question: *"What is the effect of integrating the flipped classroom and think-aloud strategies in teaching general mathematics on developing self-efficacy in mathematics among female preparatory-year students?"*, the validity of the second research hypothesis was tested: *"There is a statistically significant difference between the mean scores of students in the experimental group and those in the control group in the post-test of self-efficacy in mathematics, favoring the experimental group. This difference is attributed to the teaching strategy"* (see Table 9).

Domains	Experimental		Control		df	t	p	η^2	d
	M	SD	M	SD					
Mathematical language and its use	16.34	2.485	11.16	1.12	78	12.019	0.000**	0.65	2.54
Mathematical reasoning in problem-solving	16.31	1.857	12.18	1.015	78	12.342	0.000**	0.66	2.76
Solving mathematical tasks	23.89	2.542	15.64	1.89	78	16.472	0.000**	0.78	3.68
Whole	56.60	2.82	39.24	4.22	78	21.632	0.000**	0.85	4.83

Table 9: Results of the T-test for the Posttest of the Mathematical Self-efficacy Scale

Note. ** p < 0.01.

Table 9 shows a statistically significant difference ($p < 0.01$) between the mean scores of the experimental and control groups in the posttest of the mathematical self-efficacy scale, favoring the experimental group in both the overall test and all its subdomains. This confirms the acceptance of the second research hypothesis, which stated, "*There is a statistically significant difference between the mean scores of students in the experimental group and those in the control group in the post-test of self-efficacy in mathematics, favoring the experimental group. This difference is attributed to the teaching strategy*."

Additionally, Table 9 indicates that the effect size of the independent variable (integration of the flipped classroom and think-aloud strategies) on the dependent variable (self-efficacy in mathematics) is large, with a Cohen's d value of 4.83. This demonstrates a very strong effect and a high level of effectiveness in enhancing self-efficacy in mathematics through the integration of these two teaching strategies.

Discussion

The findings of this study indicate statistically significant differences at the 0.01 significance level between the mean scores of the experimental and control groups in the post-test of deep understanding, favoring the experimental group. The effect size was also large. Similarly, there were statistically significant differences at the 0.01 significance level in the post-test of self-efficacy in mathematics, again favoring the experimental group, with a large effect size. This highlights the impact of integrating the flipped classroom and think-aloud strategies in teaching general mathematics on enhancing deep understanding and self-efficacy among the participants.

Since both groups were equivalent in the pre-test, the observed differences in the post-test can be attributed to the use of the flipped classroom and think-aloud strategies in the experimental group, whereas the control group did not receive this treatment. These findings align with previous studies (Al-Sadi & Al-Hadi, 2024; Alshahrni & Al-Kawafeha, 2019; Bjorn et al., 2019; Chou, 2018; Hava, 2021; Sari et al., 2019; Shao & Liu, 2021; Sun et al., 2023) that examined the effectiveness of both strategies on various learning outcomes. One explanation is that the integration of multiple learning modes, including blended, synchronous, and asynchronous learning, along with self-directed and constructivist learning approaches, encouraged students to construct their own knowledge and engage more actively in acquiring mathematical concepts.

Moreover, the flipped classroom environment fosters a comfortable and supportive atmosphere, enabling students to ask questions with confidence, address learning difficulties, and study at their own pace, in their preferred way and setting. It also allows them to review missed content, engage with peers' contributions, and enhance self-regulation skills, leading to greater accuracy in problem-solving.

Another reason could be that the flipped classroom model helped optimize face-to-face instructional time, allowing more focus on interactive learning and in-depth discussions. The integration of think-aloud strategies further supported content mastery by helping students form mental representations of mathematical concepts, thereby improving deep understanding. Additionally, technology-enhanced instruction provided a stronger visual and interactive learning experience compared to traditional text-based materials. This likely contributed to better concept retention and greater comprehension of mathematical principles.

These findings align with Bergman and Sams (2015), who suggested that flipped learning leads to deeper understanding. In traditional classrooms, lower-order thinking skills (such as recall and basic understanding) often dominate class time, leaving little room for higher-order skills (analysis, evaluation, and synthesis). However, the flipped classroom model shifts lower-order learning outside the classroom through technology-based content delivery, allowing more in-class focus on higher-order thinking, ultimately resulting in deeper learning. Hussain et al. (2023) also supports this, stating that the flipped classroom model enhances understanding of complex topics by introducing concepts before class, giving students time to process information. In-class activities then reinforce understanding, correct misconceptions, and facilitate knowledge application, leading to deeper comprehension.

The think-aloud strategy played a key role in promoting active engagement and cognitive processing. It created opportunities for positive interaction during learning, encouraging students to engage in both cognitive and metacognitive activities. This enhanced critical thinking, problem-solving skills, and the ability to generate multiple solutions, rather than relying on rote learning. By actively verbalizing their thought processes, students became more engaged in learning, applied their knowledge to new situations, and developed greater enthusiasm for mathematics. This strategy also supported the functional acquisition of mathematical concepts, which contributed to deeper understanding and increased self-efficacy in mathematics.

The self-directed learning component of the flipped classroom allowed students to take ownership of their learning process, reinforcing their confidence and belief in their ability to succeed. Through independent study at home, students were able to explore concepts at their own pace, complete assignments independently, and later engage in collaborative learning during class through think-aloud activities. This process enhanced their self-confidence, strengthened their ability to solve problems autonomously, and ultimately contributed to higher self-efficacy in mathematics. Sun et al. (2023) further supports this, noting that self-efficacy and engagement in flipped classrooms form a mutually reinforcing cycle. Self-efficacy acts as both a motivator and an outcome, enhancing student participation, which in turn leads to better academic and psychological outcomes. As students experience success in the flipped classroom, their self-efficacy strengthens, creating a continuous cycle of improvement.

Conclusion

The purpose of this research was to examine the impact of integrating the flipped classroom strategy with the think-aloud technique on enhancing deep understanding and self-efficacy in mathematics among preparatory-year female students. The results showed that the experimental group, which received instruction through this integrated approach, outperformed the control group in both deep understanding and self-efficacy, with statistically significant differences and large effect sizes. These findings highlight the effectiveness of combining modern teaching strategies to improve cognitive and affective learning outcomes. The study recommends that university faculty members adopt this instructional integration and receive appropriate training to maximize its benefits. Future research could explore the long-term impact of these strategies across different mathematical disciplines and diverse student populations. Implementing these strategies in mathematics instruction can enhance students' conceptual understanding, engagement, and confidence, contributing to improved learning experiences in higher education.

Ethics Approval and Consent to Participate

The research was approved by the Ethics Committee of the Imam Abdulrahman Bin Faisal University (IRB Number: IRB-2025-15-0221). The research was conducted in accordance with the Declaration of Helsinki.

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