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Original Paper

Enhancing Mathematical Conceptual Understanding and Computation Skills of Grade Nine Learners through Team-Based Learning Strategies

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Abstract

This study explores into the effectiveness of Team-Based Learning (TBL) as a pedagogical intervention aimed at bolstering mathematical computation skills and fostering deeper conceptual understanding among ninth-grade students. Conducted at Sherubling Higher Secondary School in Bhutan, this research directly addresses a concerning and persistent decline in mathematics performance observed within this specific student demographic. TBL is conceptualized and implemented as a highly structured, collaborative pedagogical approach meticulously designed to cultivate active student engagement and significantly improve learning outcomes. The methodological framework adopted for this investigation was a sequential explanatory mixed-methods design, involving a cohort of 53 Grade Nine students. Comprehensive data collection encompassed pre- and post-intervention assessments of both conceptual understanding and computational proficiencies, alongside detailed attitude surveys and systematic classroom observations. The quantitative analysis yielded compelling evidence of TBL's positive impact, revealing a statistically significant 14% improvement in students' average mathematics scores, which rose from an initial 51% to a post-intervention 65%. This substantial gain underscores the efficacy of the TBL approach in enhancing academic performance. Furthermore, qualitative data, gathered through various observational and survey instruments, consistently indicated that TBL profoundly influenced student engagement, actively promoted collaborative learning behaviors, and fostered more positive attitudes towards mathematics. It is noteworthy, however, that a segment of the student population continued to express a preference for individual learning modalities. Collectively, these findings robustly highlight TBL's considerable potential as a valuable and transformative educational strategy, capable of not only boosting academic proficiency in mathematics but also of developing crucial 21st-century skills, such as effective teamwork, critical thinking, and problem-solving abilities.

Keywords: Team-Based Learning, Mathematics Education, Conceptual Understanding, Computational Skills, Student Engagement, Collaborative Learning, Bhutanese Education

1. Introduction

Contemporary mathematics education continuously seeks innovative pedagogical approaches to foster critical thinking, enhance student engagement, and improve learning effectiveness. A significant shift in modern educational philosophy advocates for student-centered and interactive learning environments, moving beyond traditional, passive, lecture-based instruction. While cooperative learning strategies are widely recognized and recommended within mathematics education, there remains a notable gap in providing clear, structured guidance for their effective implementation in classroom settings.

This research endeavors to explore Team-Based Learning (TBL) as a structured, alternative pedagogical strategy specifically designed to enhance mathematical computation skills among ninth-grade learners. TBL is characterized by its emphasis on active student participation, structured peer collaboration, and the pursuit of conceptual mastery through well-defined group activities. In contrast to conventional teaching methods, which often rely on students' passive absorption of content, TBL actively encourages students to engage in problem-solving, collaborative discussions, and peer feedback. This approach is anticipated to strengthen both students' computational proficiency and their interpersonal communication skills. Although cooperative learning does not entirely supplant the necessity of direct instruction, it furnishes invaluable opportunities for students to collectively identify and address common mathematical misconceptions through shared collaborative tasks. Extensive research consistently demonstrates that interactive learning, wherein students actively read, write, speak, and collaborate on mathematical concepts, substantially enhances comprehension and promotes long-term retention of knowledge. By systematically integrating TBL into mathematics instruction, this study endeavors to bridge the existing theoretical-practical divide between recommendations for cooperative learning and their tangible application in the classroom. Ultimately, this intervention seeks to elevate students' mathematical abilities, instill greater confidence in their problem-solving capacities, and cultivate a supportive, collaborative learning environment. The overarching aim is to demonstrate how structured teamwork, guided peer interactions, and targeted problem-solving activities can collectively transform mathematics education into a more dynamic, engaging, and genuinely learner-centered experience, preparing students for both academic success and real-world challenges.

This study is significant as an initial effort to assess the extent of students' proficiency in solving mathematical problems accurately within the appropriate mathematical context. The research aims to analyze students' errors in computational skills when solving tasks, with a focus on their mathematical resilience. Specifically, it examines students' misconceptions and errors in conceptualizing mathematical problems, including errors related to comprehension, transformation, and process skills, particularly in the context of word problems. Furthermore, the study seeks to evaluate these errors in relation to students' mathematical abilities and to identify effective strategies for enhancing learners' conceptual understanding and computational skills in solving mathematical problems.

1.1 Rationale

Over the past three academic years, Sherubling Higher Secondary School has observed a consistent and concerning decline in the performance of its Grade Nine students in mathematics. This persistent downward trend has resulted in an increasing number of academic failures, prompting significant apprehension among both school faculty and management. Such a situation underscores an urgent imperative to critically evaluate and, if necessary, reform existing teaching and learning strategies within the mathematics curriculum.

Initial diagnostic indicators further validate the severity of this issue. Standardized test scores consistently fall below expected benchmarks, while classroom observations reveal a prevalence of incomplete homework assignments and a noticeable lack of motivation among students when engaging with mathematical concepts. These symptoms collectively point to a fundamental challenge in fostering deep conceptual understanding and robust computational skills, which are foundational for success in higher-level mathematics and other STEM fields.

While various pedagogical interventions have been explored in educational research, this study postulates that the current decline necessitates a targeted and structured approach. The existing problem statement in the previous researches indicated to a broader set of interventions, including lessons based on multiple intelligences, positive reinforcement for homework completion, and general group work activities. However, to achieve precise alignment with the overarching research focus on Team-Based Learning (TBL), these general strategies are now refocused. This research specifically addresses the potential of Team-Based Learning (TBL) as a highly structured, collaborative pedagogical strategy designed to directly counteract the observed decline in mathematical proficiency. TBL, with its emphasis on individual accountability within a team context, readiness assurance processes, and application-focused problem-solving, offers a promising framework to enhance both students' conceptual understanding and their computational fluency in mathematics. Therefore, the core issue this study seeks to address is the ineffectiveness of current, less structured pedagogical approaches in cultivating sustained engagement and profound learning in mathematics, a gap that TBL is uniquely positioned to bridge through its systematic and learner-centered design.

1.2 Situational Analysis

Modern educational paradigms in Bhutan, evolving from a foundational emphasis on literacy and numeracy, now advocate for holistic student development. This shift, however, has inadvertently led to a decline in academic rigor, particularly within subjects demanding interactive and collaborative learning, such as mathematics and the sciences. This challenge is not isolated to Bhutan but reflects a global trend where students exhibit diminished engagement and proficiency in mathematics. A significant contributing factor is the prevalent difficulty students encounter in connecting abstract mathematical concepts to real-world applications. This issue is particularly pronounced in tasks requiring conceptual understanding, where students must translate contextual scenarios into mathematical frameworks, thereby impacting their computational skills. The traditional pedagogical approach, often characterized by didactic instruction, frequently fails to bridge the gap between theoretical mathematical knowledge and its practical application. Students struggle to internalize academic concepts when presented through conventional methods, despite the critical need for these concepts in future professional contexts. The expectation for students to independently forge connections between classroom learning and real-world relevance, without explicit instructional support, exacerbates these difficulties. The Grade Nine mathematics curriculum in Bhutan, which prioritizes conceptual understanding over rote memorization across strands such as numbers and operations, algebra, geometry, measurement, and data and probability, presents a significant hurdle. The transition from Grade Eight to Grade Nine often involves an increased complexity in problem presentation, requiring advanced conceptual understanding to translate and formulate mathematical solutions. Students' struggles in mathematics are multifaceted, often stemming from challenges in comprehending and applying mathematical principles. These difficulties are particularly evident in tasks that demand the translation of contextual information into mathematical expressions, which directly impacts their computational accuracy. Students frequently encounter obstacles in grasping the underlying meaning and context of mathematical problems, impeding their ability to identify the core mathematical challenge and formulate an appropriate solution strategy. A significant challenge lies in students' limited ability to transform everyday language into precise mathematical sentences for computational difficulties. This involves accurately identifying variables, relationships, and operations required to solve a problem. The inability to effectively analyze and interpret problem statements leads to errors in setting up the mathematical model, thereby affecting the accuracy of subsequent computations. Furthermore, beyond initial comprehension and translation, students often exhibit weaknesses in executing the procedural steps necessary for problem-solving, further impacting their computational outcomes.

These challenges are not merely academic but also influence students' attitudes towards mathematics. The 2013 National Education Assessment in Bhutan highlighted a discrepancy between examination performance and continuous assessment, suggesting a systemic issue in how students apply their knowledge under formal conditions. Furthermore, the assessment underscored the critical role of language proficiency, noting that students with lower linguistic abilities face particular hurdles in developing conceptual understanding in mathematics. Given the pervasive nature of these difficulties, a re-evaluation of current teaching methodologies is essential. The traditional didactic approach often proves ineffective in fostering deep conceptual understanding and catering to diverse learning styles. There is an urgent need for interactive and collaborative learning strategies that can enhance student engagement and cultivate a positive disposition towards mathematics. Team-Based Learning (TBL) emerges as a promising pedagogical intervention, offering a structured approach to address these challenges. By engaging students in collaborative problem-solving, TBL can facilitate a more profound conceptual understanding of mathematical principles and refine their ability to construct accurate mathematical sentences for computational difficulties.

Team-Based Learning provides a framework where students actively participate in learning, moving beyond passive reception of information. In this collaborative environment, students are encouraged to enhance their conceptual understanding through peer discussion and collective problem-solving. This collaborative process allows for varied perspectives on problems, helping students to better interpret and contextualize mathematical tasks that previously presented as challenges to their conceptual understanding. Furthermore, working in teams, students can practice and refine their ability to transform real-world scenarios into precise mathematical sentences for computational difficulties. This includes identifying relevant information, formulating equations, and structuring their approach to solve complex problems. The collective effort in analyzing and interpreting problem statements helps to mitigate individual errors in computational setup. Finally, TBL fosters the development of effective problem-solving strategies, as students learn from each other's approaches and collectively refine their procedural execution, leading to improved accuracy and efficiency in mathematical computations.

This research aims to investigate the efficacy of Team-Based Learning in enhancing mathematical computation skills and conceptual understanding among Grade Nine mathematics learners. Specifically, the study will examine the impact of TBL on students' ability to develop conceptual understanding in mathematics, particularly in tasks that require interpreting contextual information. It will also analyze how TBL influences students' proficiency in constructing accurate mathematical sentences for computational difficulties by improving their skills in analyzing and interpreting problem statements. The research will further identify the specific mechanisms within TBL that contribute to improved mathematical computation skills and conceptual understanding as a strategy to further enhance comprehension and problem-solving abilities.

1.3 Objectives of the Study

By focusing on these objectives, this study seeks to provide empirical evidence for the benefits of TBL as a pedagogical approach to address the persistent challenges in mathematics education. The findings are expected to offer valuable insights for educators, curriculum developers, and policymakers in designing more effective and engaging learning experiences that foster both strong computational skills and deep conceptual understanding in mathematics.

2. Literature Review

The enduring challenge of mathematical understanding and computation

The persistent challenge in mathematics education involves fostering both profound conceptual understanding and proficient computational abilities concurrently. This difficulty stems from a cognitive dissonance experienced by learners, where their intuitive, often concrete, understanding clashes with the abstract, logical, and formal frameworks intrinsic to mathematical reasoning (Treacy & Leavy, 2023; Susac et al., 2014). This is not merely a knowledge gap but a conflict between cognitive frameworks, where every day mental models can hinder the acquisition of accurate mathematical principles, necessitating a deliberate process of conceptual change (Merenluoto, 2006). Student difficulties manifest in several interconnected areas, leading to a series of learning obstacles. Fundamental weaknesses, such as an incomplete mastery of number facts and computational procedures, consume vital cognitive resources that should be directed towards higher-order problem-solving (Jordan, 2010; Fuchs et al., 2016). Moreover, Jordan (2010) mentioned that students often possess inert and compartmentalized knowledge, resulting in a significant inability to transfer concepts learned in one context to new or unfamiliar situations. This is further complicated by deficiencies in complex problem-solving, which requires an integrated application of reading comprehension, logical reasoning, and computational execution (Boonen et al., 2016). Underlying these challenges are the inherent cognitive demands of mathematics itself. Mathematical proficiency necessitates the active engagement of critical mental processes, including working memory for holding and manipulating information, logical reasoning for deducing pathways, and language comprehension for interpreting problems (Raghubar et al., 2010; Mestre, 2013). Effective learning involves navigating the delicate interplay between intuitive insight, which offers initial guidance, and formal rigor, which is essential for validation and generalization (Inglis & Aberdein, 2015). Consequently, these multifaceted challenges render traditional, passive instructional models—focused on rote memorization and procedural drills—profoundly inadequate. A pedagogical imperative exists to transition towards active learning environments that strategically engage students in higher-order cognitive tasks (Vale, 2023). This involves guiding learners to synthesize information, deconstruct and analyze complex problems, compare diverse solution strategies, and critically evaluate outcomes (Vale, 2023). By immersing students in activities that require them to read, write, discuss, and collaborate on mathematical concepts, education can foster a deep, integrated, and durable understanding that goes beyond mere calculation and embodies true mathematical proficiency (Rittle-Johnson & Star, 2009).

The imperative of mental involvement for conceptual understanding in mathematics

Effective pedagogy transcends the mere transmission of information from instructor to student; it necessitates a profound mental involvement and active engagement on the part of the learner (Bransford, Brown, & Cocking, 2000). This perspective fundamentally challenges the traditional notion that learning is a passive reception of knowledge, akin to an automatic pouring of facts into students' minds. Instead, it posits that genuine learning, particularly in complex domains such as mathematics, is an active constructive process demanding significant student activity and cognitive effort (Bransford et al., 2000). Students frequently encounter substantial difficulties in achieving deep conceptual understanding in mathematics and science, often because their pre-existing intuitive frameworks for comprehending the world conflict with the abstract and logical structures inherent in these disciplines (Fellows, 1994). This cognitive dissonance creates a barrier to the assimilation of new, scientifically accurate concepts. Modern educational demands further exacerbate this challenge, as students are increasingly expected to leverage their cognitive development, academic knowledge, and linguistic proficiencies to perform a wide array of higher-order thinking tasks. These include, but are not limited to, reading critically, comprehending complex texts, synthesizing disparate information, analyzing problems, comparing and contrasting different approaches, relating concepts, articulating ideas, writing coherent arguments, and evaluating solutions (Herrera, Murry, & Cabral, 2012). Consequently, there is an urgent need for the implementation of appropriate teaching strategies that not only enhance learning but also support a paradigm shift from assessment of learning to assessment as learning. Such strategies enable educators to distinctly measure incremental gains in academic performance and conceptual mastery. Despite numerous global efforts by educationists and researchers to mitigate difficulties in teaching science and mathematics—ranging from upgrading teacher qualifications to implementing innovative learning methods—optimal results remain elusive due to persistent constraints in practical classroom settings (Bransford et al., 2000). This is evident in the observed struggles of students in mastering mathematical material, particularly their inability to effectively identify and solve word problems, which are crucial for developing a nuanced understanding of mathematical concepts (Bransford et al., 2000).

Learning mathematics is intrinsically linked to the development of logical reasoning, positioning it as a foundational science. The process of learning mathematics is inherently a thought process, requiring significant mental activity. Individuals are considered to be thinking when they engage in mental operations, and thus, studying mathematics inherently demands such cognitive engagement. During this mental activity, learners actively construct relationships between pieces of information stored in their minds, thereby forming meaningful connections and building robust conceptual frameworks. Contextual comprehension, in particular, plays a pivotal role in this process, as it compels students to confront the practical nature of mathematical challenges, thereby deepening their conceptual understanding of how mathematical principles apply to real-world scenarios (Bransford et al., 2000).

Pedagogical Imperatives: Cultivating Higher-Order Thinking for Conceptual Mastery

The persistent difficulties students face in attaining genuine conceptual understanding call for a fundamental shift in teaching methods, moving beyond traditional didactic approaches. This shift requires pedagogical frameworks explicitly designed to develop higher-order thinking skills, engaging students in analytical, synthetic, and evaluative processes that are essential for deep mathematical reasoning (Hattie & Timperley, 2007). Effective strategies are thus identified by their ability to foster active, cognitively rich learning environments. Such pedagogical approaches must be purposefully designed to achieve several interconnected goals. Primarily, they should promote active learning by replacing passive knowledge reception with activities involving discussion, collaborative problem-solving, and articulation of reasoning, compelling students to confront and refine their own understanding. Simultaneously, these strategies need to systematically address students' pre-existing conceptions, acknowledging and intentionally restructuring intuitive—and often conflicting—mental models to align with formal mathematical principles, which is crucial for meaningful conceptual change (Posner, Strike, Hewson, & Gertzog, 1982). Moreover, the heart of these methodologies involves deliberately fostering cognitive development. Instruction should be tailored to equip students with the necessary tools for intellectual engagement, such as the abilities to analyze, synthesize, compare, and evaluate mathematical information. Finally, a key component is the integration of assessment as a dynamic learning instrument. By using real-time feedback to detect conceptual obstacles and adjust instruction accordingly, educators can establish responsive feedback loops that support incremental mastery and academic progress (Bransford et al., 2000). The overarching goal is to implement classroom practices that empower students to internalize and independently apply these higher-order skills, thereby achieving a sophisticated and flexible understanding of mathematical concepts.

Cooperative Learning: A Social Constructivist Framework for Enhancing Mathematical Proficiency

The documented challenges in fostering deep conceptual understanding and robust procedural fluency in mathematics have prompted a significant pedagogical shift towards student-centered approaches. Among these, cooperative learning has emerged as a foundational and extensively researched instructional paradigm. Rooted in social constructivist theory, particularly Vygotsky's (1978) concept of the Zone of Proximal Development, cooperative learning is predicated on the understanding that knowledge is actively constructed through social interaction and dialogue. It is not merely a synonym for group work; rather, it is an umbrella term for a family of structured instructional techniques—including Student Teams-Achievement Divisions (STAD), Jigsaw, and Group Investigation—that are systematically designed to create positive interdependence and individual accountability within learning groups (Johnson & Johnson, 2009). The efficacy of cooperative learning is governed by five essential elements, as defined by Johnson and Johnson (2009): (1) Positive Interdependence, where students perceive that their success is linked to the success of their group members; (2) Individual Accountability, which ensures that each member is responsible for their contribution and learning; (3) Promotive Interaction, characterized by individuals encouraging and facilitating each other's efforts; (4) Social Skills, requiring the direct teaching of interpersonal skills; and (5) Group Processing, where teams reflect on their collaborative effectiveness. When these elements are explicitly implemented, the classroom transforms into a micro-society of learners working towards shared goals.

Meta-analyses of hundreds of studies consistently demonstrate that well-structured cooperative learning environments lead to significant gains in student achievement across diverse subject areas, with particularly strong effect sizes in mathematics (Kyndt et al., 2013; Slavin, 2014). The mechanisms driving this improvement are multifaceted. The environment of peer-to-peer interaction and mutual support provides a low-stakes forum for students to externalize their reasoning, articulate their thought processes, and engage in cognitive conflict. According to Webb (2009), verbalization forces a clarification of thought, while hearing alternative perspectives from peers can disrupt misconceptions and scaffold understanding in a more accessible language than traditional lecture. Specifically, within mathematics education, the benefits of cooperative learning are profound. The collaborative process facilitates the "pooling of diverse insights," allowing students to approach a single problem from multiple angles. This diversity not only simplifies the recognition of correct solutions but, more importantly, illuminates the underlying mathematical structure and the validity of various solution pathways (Boaler, 2016). In the study by Hiebert and Grouws (2007) stated that while one student may approach an algebra problem procedurally, another may conceptualize it visually; their collaboration requires them to justify their methods and forge connections between different representations, thereby stimulating critical thinking and deepening conceptual understanding. Furthermore, the study by Kagan & Kagan (2009) also stated that the social support inherent in cooperative groups can mitigate mathematics anxiety and foster a growth mindset, creating a classroom culture where struggle is viewed as a natural part of the learning process. Thus, cooperative learning represents a powerful pedagogical response to the limitations of traditional, transmission-based models of mathematics instruction. By intentionally structuring social interaction around well-defined learning tasks, it leverages the collective intelligence of the classroom to enhance individual achievement. Its strength lies in its dual focus on cultivating both the cognitive skills necessary for mathematical proficiency and the socio-affective dispositions—such as increased engagement, motivation, and self-efficacy—that support long-term academic success.

Team-Based Learning: A Structured Framework for Collaborative Learning

While cooperative learning provides a strong philosophical foundation for collaborative work, Team-Based Learning (TBL) emerges as a distinct, highly structured pedagogical system designed to ensure its principles are consistently and effectively implemented. Developed by Dr. Larry Michaelsen, TBL is a comprehensive instructional strategy that transforms the classroom into a dynamic environment of accountability, collaboration, and application. Its power lies not in being "group work," but in its meticulously sequenced framework that systematically integrates individual preparation with collaborative problem-solving, creating a synergistic cycle of learning (Michaelsen & Sweet, 2008).

The TBL process is a multi-stage, repeatable cycle consisting of two primary phases: Readiness Assurance and Application.

1. The Readiness Assurance Process: Building a Foundation of Conceptual Understanding

This initial phase ensures students arrive in class prepared to engage in higher-order learning, addressing a common flaw in less structured group work.

- Individual Readiness Assurance Test (iRAT): This short, individual, closed-book quiz on preparatory materials (e.g., readings, video lectures) establishes non-negotiable individual accountability. It ensures every student engages with foundational concepts before team interaction, creating a necessary baseline of knowledge.

- Team Readiness Assurance Test (tRAT): Teams immediately retake the same assessment, typically using an Immediate Feedback Assessment Technique (IF-AT) scratch card. This is the engine of peer learning. The process forces discussion, debate, and peer teaching as students must convince one another of their answers and reach a consensus. Immediate feedback corrects misconceptions on the spot and reinforces accurate understanding (Haidet et al., 2014).

- Instructor Clarification and Appeals: The instructor then addresses persistent misconceptions revealed by the tRAT. The appeals process, where teams can formally contest answers with evidence, further deepens conceptual engagement and refines students' ability to construct logical arguments.

2. Application-Focused Exercises: Developing Procedural Fluency and Critical Thinking

This phase constitutes the majority of class time and is where deeper learning occurs. Teams work on significant, complex problems that adhere to the "4S" framework:

- Significant Problem: The problem is authentic and mirrors real-world challenges.
- Same Problem: All teams work on the same problem simultaneously.
- Specific Choice: Teams must make a specific, defendable decision.
- Simultaneous Report: Teams report their decisions at the same time, fostering a culture of comparative discussion and debate.

In mathematics, Michaelsen stated that these exercises are crucial for bridging the gap between conceptual understanding (from the Readiness Assurance Process) and computational fluency. Students must apply formulas and procedures to solve non-routine problems, justifying their reasoning and evaluating the strategies of other teams. This moves learning beyond rote calculation to strategic, adaptive problem-solving.

Pedagogic Relevancy of TBL in learning Mathematics in Bhutanese context.

The implementation of Team-Based Learning (TBL) in Bhutanese mathematics education strategically aligns an innovative teaching method with the nation's educational objectives. This structured pedagogical approach offers a systematic solution to persistent challenges in mathematics learning, while simultaneously upholding Bhutan's holistic educational values. For institutions such as Sherubling Higher Secondary School, TBL provides a practical method to enhance both the conceptual understanding and computational abilities of Grade Nine students through its meticulously designed learning activities. The potential advantages of TBL within the Bhutanese context are diverse, directly addressing identified learning deficiencies. The methodology's emphasis on ensuring readiness and applying knowledge through exercises naturally bridges students' intuitive comprehension with formal mathematical concepts. Concurrently, group discussions foster a supportive environment where students can articulate and refine their mathematical reasoning. A primary benefit of TBL is its capacity to improve problem-solving skills by engaging groups in authentic, complex problems that require the integration of both linguistic and mathematical resources. Furthermore, this model promotes a deeper conceptual understanding by compelling students to justify their reasoning and strengthens computational skills through the consistent application of methods in purposeful scenarios. Additionally, TBL's inherent structure cultivates higher-order thinking skills and accommodates diverse learning needs through organic peer tutoring, thereby creating an inclusive learning environment that benefits both advanced and struggling learners.

However, the effective adoption of this model hinges on a thorough assessment of various contextual elements. Essential teacher training is paramount, requiring professional development focused on TBL methodologies, effective facilitation strategies, and managing group interactions. Aligning the curriculum strategically is vital to ensure that TBL activities directly support established learning objectives and supplement traditional direct instruction. When properly contextualized, TBL stands as a powerful catalyst for mathematical excellence in Bhutan, offering a robust framework that transforms mathematics instruction into a dynamic, engaging experience. Its systematic approach not only addresses immediate learning challenges but also cultivates the collaborative skills and positive dispositions toward mathematics that align with Bhutan's broader educational vision, ultimately preparing students for both academic success and life challenges beyond the classroom.

Thus, this study is undertaken to contribute to the existing discussions on the relevance of the use of TBL as a technique to enhance Mathematical Conceptual understanding and Computation Skills in Grade Nine learners at Sherubling Higher Secondary School, Trongsa District. The study attempts to find out the attitude of learners towards TBL strategy in learning mathematics in the classroom. The researcher will also unravel the pedagogic relevance of TBL in the classroom and how its use facilitates learners' conceptual comprehension and enhance classroom participation.

3. Methodology

A research methodology refers to the structured process and set of procedures employed to conduct research efficiently and effectively. According to Creswell (2003), research methodologies generally fall into three categories: quantitative, qualitative, and mixed methods approach. Quantitative methods involve structured, numerical data collection and analysis, while qualitative methods emphasize unstructured, narrative data. Mixed methods research combines elements of both to gain a comprehensive understanding of phenomena. The research adopted a sequential explanatory mixed-methods design. This approach entailed collecting and analyzing quantitative data first, followed by qualitative data in two distinct phases. The rationale was to quantitatively measure the effect of a Team-Based Learning (TBL) intervention on students' mathematical achievement, then further explore those quantitative outcomes through qualitative inquiry to understand the underlying reasons and mechanisms behind the results. This design thus facilitated both numerical measurement and rich contextual insights into the intervention's effectiveness.

3.1 Participants and Setting

The research targeted Grade Nine students at Sherubling Higher Secondary School, comprising a total sample of 53 students aged 14 to 16 years. The cohort reflected heterogeneous abilities and participated voluntarily. Participants were selected through purposive sampling, chosen deliberately to align with the study's objectives (Trochim, 2006). Ethical protocols were followed strictly: formal permission was secured from the school administration, and informed consent was obtained from the students and the parents of minors. The study was carried out within the standard mathematics classroom environment to minimize disruptions to regular school activities and to simulate authentic learning conditions.

3.2 Data Collection Instruments

Three primary instruments were employed to collect data:

1. Previous year's Mathematics Score (Baseline data)

These scores provide a foundational baseline of students' existing knowledge that allow researchers to account for initial variations among participants and also to evaluate the effectiveness of educational interventions.

2. Conceptual and Computational Test (Quantitative)
A standardized, researcher-developed test covered key Grade Nine mathematics topics such as algebra, trigonometry, geometry, and statistics. The test comprised a balanced combination of questions that assessed conceptual understanding (e.g., problem-solving applying mathematical principles) and procedural computation accuracy (e.g., algorithmic calculations). This test was administered both before (pre-test) and after (post-test) the TBL intervention to measure students' progress. Its reliability and validity were ensured through expert review and pilot testing procedures.

3. Attitude Survey (Mixed Methods)
To explore students' perceptions and attitudes toward mathematics, teamwork, and TBL, a mixed-methods attitude survey was used. The survey integrated quantitative Likert-scale items (e.g., a 5-point scale from Strongly Disagree to Strongly Agree) to capture measurable attitude changes, alongside open-ended questions that elicited qualitative insights reflecting students' feelings, opinions, and recommendations regarding the learning experience.

3.3 Intervention and Data Collection Procedures

The study was implemented over an 18-week period, segmented into three phases for clarity and systematic data capture: baseline data collection (weeks 1–2), TBL intervention implementation (weeks 3–17), and post-intervention data collection (week 18).

Baseline Data Collection (Weeks 1–2)

During this initial phase, baseline measures of students' mathematical knowledge and attitudes were established:

- Previous year's Mathematics Score of individual participants was compiled as it provides baseline of students' existing knowledge.
- The Conceptual and Computational Test was administered under standardized conditions to measure students' initial conceptual understanding and computational skills.

Intervention Implementation (Weeks 3–17)

The 15-week TBL intervention was integrated into the regular Grade Nine mathematics curriculum. Researchers facilitated TBL modules designed to cover required topics through a structured sequence:

- *Pre-class Preparation*: Each session began with students completing assigned preparatory materials independently, such as textbook readings, instructional videos, and practice problems, ensuring foundational knowledge and accountability.
- *Individual Readiness Assurance Test (iRAT)*: At the start of each class, students individually completed a short multiple-choice task based on preparatory content to assess individual comprehension.
- *Team Readiness Assurance Test (tRAT)*: Immediately following iRAT completion, students worked in their pre-assigned teams (5–7 members) to retake the same task collaboratively. Consensus on each answer fostered peer discussion and immediate feedback.
- *Appeals Process*: Teams could challenge any incorrect answers on the tRAT by submitting a written justification grounded in the preparatory materials, encouraging critical thinking.
- *Application-Focused Exercises*: The majority of class time was devoted to authentic, complex problem-solving exercises requiring application of learned concepts, promoting higher-order thinking, decision-making, and teamwork. Teams presented and defended their solutions.
- *Ongoing Classroom Observation*: Throughout the intervention, systematic observations were conducted to document engagement, collaboration, and overall team dynamics using the structured protocol.

Post-Intervention Data Collection (Week 18)

Following the intervention, post-test data were collected to evaluate the impact:

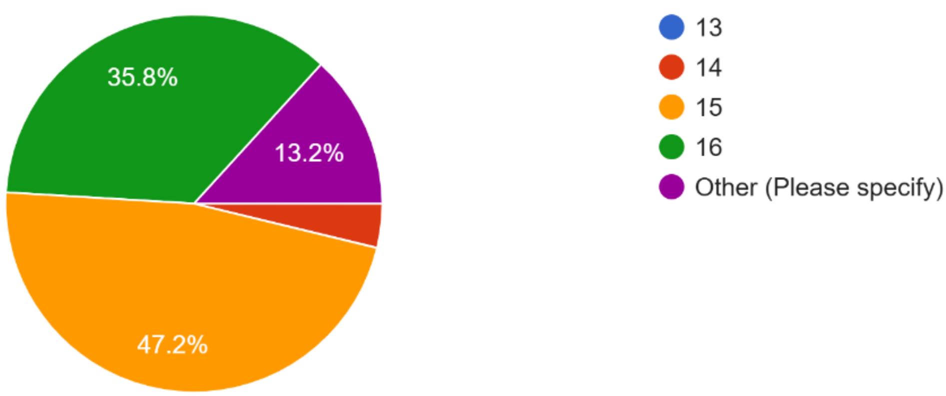
- The Conceptual and Computational Test was re-administered to quantitatively assess any changes in students' mathematical understanding and skills relative to baseline.
- The Attitude Survey was administered to determine students' attitudes toward mathematics and collaborative learning (TBL), providing both quantitative data and qualitative insights.

By collecting and analyzing both quantitative pre-post test scores, Likert-scale survey responses, and qualitative data from open-ended surveys, the research employed a rigorous sequential explanatory mixed-methods approach. The quantitative data, including test scores, was analyzed using descriptive statistics to determine the improvement in students' mathematical performance. Comparisons were made between the students' previous year's mathematics scores, which served as baseline data, and their scores on conceptual tests that assessed the same mathematical concepts. This comparison helped evaluate the impact of the Team-Based Learning strategies on student performance. The qualitative data, derived from open-ended survey responses, was analyzed thematically to identify patterns in students' attitudes and perceptions regarding mathematics and the TBL experience.

Data triangulation was employed for this study to enhance the validity and robustness of the findings by combining survey questionnaire data and conceptual test results. The survey data, which provides insights into students' attitudes and demographics, was cross-referenced with their performance on the conceptual tests to assess any correlation between improvements in mathematical skills and changes in attitudes towards mathematics and collaborative learning. The use of both quantitative data (Likert scale items, test scores) and qualitative data (open-ended responses) allowed for a more comprehensive analysis, with quantitative data offering measurable evidence of the impact of Team-Based Learning (TBL), and qualitative data providing context and deeper understanding of the reasons behind the changes in students' performance and attitudes. This triangulated approach ensured a thorough evaluation of TBL's effectiveness in enhancing mathematical computation skills among ninth-grade students, offering a holistic view of its influence on learning outcomes.

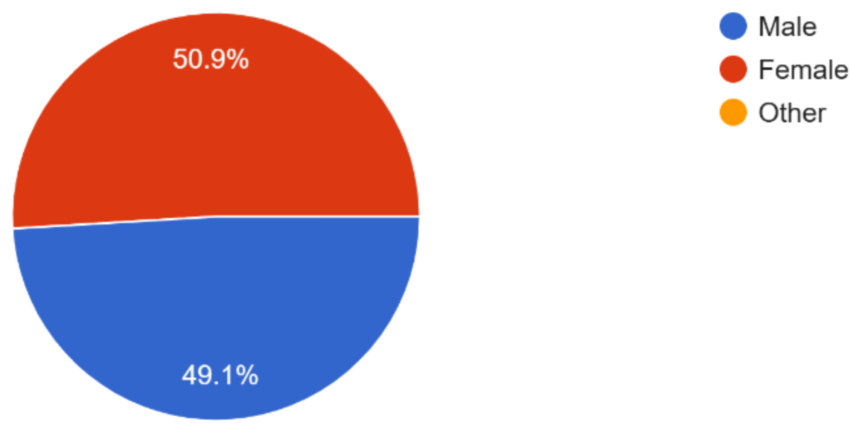
4. Results

Based on the data collected, the analysis and the interpretations are done accordingly:

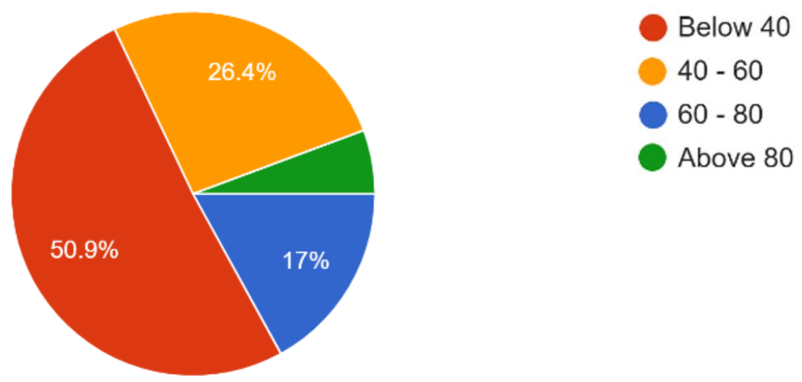


The demographic data highlighted key trends and characteristics of the survey respondents in terms of age, gender, and academic background, specifically in mathematics.

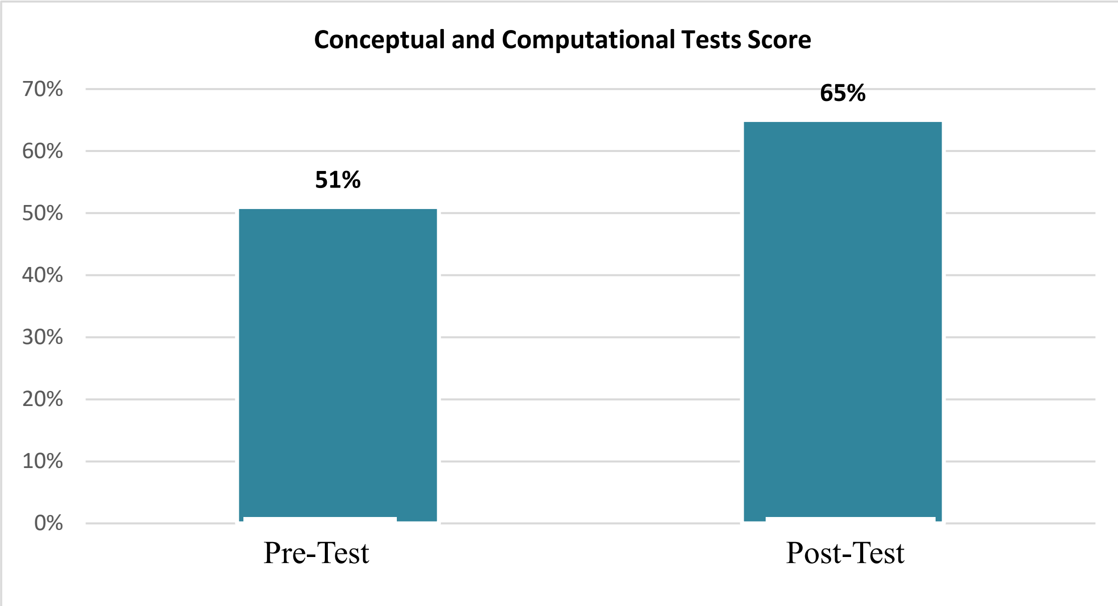
Respondents are primarily between 13 and 16 years old, with a concentration in the 15-year-old group. This suggested that the sample represents early adolescence, a key stage for academic growth and intervention. This is important transitional phase of their academic journey, interventions can be age-specific, targeting developmental needs, learning habits, and cognitive growth specific to this age range.



The survey included a balanced representation of both male and female students, ensuring gender neutrality in the findings. Out of 53 participants, 50.9% male and 49.1% female participated in the survey, ensuring that gender bias is minimal in the sample population. This balance supported the idea that the results are not skewed by gender and that any conclusions drawn will apply equally to both groups.



The data revealed a critical need for academic support in mathematics, as more than half of the respondents scored below 40 in their previous year's mathematics score. This indicated that the majority of students face significant challenges with the subject and may require targeted interventions such as remedial classes, tutoring, or curriculum adjustments. The smaller groups in the higher score brackets suggested that only a few students are excelling in mathematics, further underscoring the need for educational improvements and individualized support to boost overall performance.



Conceptual and Computational Test	Score	Remarks
Pre-Test	51%	Increased by 14%
Post-Test	65%	

The analysis of students' conceptual test scores revealed a significant improvement following the intervention of Team-Based Learning (TBL) to enhance mathematical computation skills. Prior to the intervention, students had an average score of 51% in mathematics, serving as their baseline. After participating in the TBL strategy, their mathematical conceptual scores increased to 65%, reflecting a 14% improvement. This indicated that the TBL approach effectively boosted students' understanding and mastery of mathematical concepts.

Learners' attitude survey:

Items	Strongly Agree	Agree
I enjoy learning mathematics.	13%	47%
I feel confident when solving math problems.	15%	53%
Working in Team helps me understand math better.	42%	38%
I am more motivated to study math when I collaborate with my classmates.	7%	40%
Mathematics is an important subject for my future.	55%	30%
I find math challenging but rewarding.	23%	34%
I prefer working on math problems by myself rather than in a Team.	15%	38%
I feel that Team work in math helps me learn from my peers.	23%	53%
I believe that my math skills improve when I work with others.	25%	38%
Collaborative learning makes math more interesting for me.	36%	34%

The survey shed light on Grade Nine students' perspectives on Team-Based Learning as a method to improve mathematical computation skills. While 60% of students enjoyed learning mathematics, only 68% felt confident in solving math problems. Most students (80%) believed that Team work enhanced their understanding of math, though only 47% feel motivated to study math when collaborating with peers. Mathematics is considered crucial for the future by 85% of students. Although 57% find math both challenging and rewarding, opinions are divided on individual versus group work, with 53% preferring to work alone. Group learning is highly valued for fostering peer learning (76%) and improving math skills (63%). Furthermore, 70% agreed that collaborative learning made math more engaging. Overall, the findings suggested a generally positive attitude toward team-based strategies, although some students still leaned toward working independently.

1. Describe a time when working in a Team helped you solve a difficult math problem. What did you learn from that experience?

Many students found team work helpful for improving their understanding of math problems, with several mentioning that collaboration made problem-solving easier and less stressful. They appreciated learning from peers, whether through discussions that clarified concepts like trigonometry or by working together to solve problems. Group work also boosted their confidence, with many feeling more comfortable and supported while solving difficult problems. However, some students preferred teaching their peers instead of receiving help, while others did not find Team work beneficial, citing disagreements or lack of collaboration. Some students initially struggled with certain topics but found clarity after discussing them in Teams. Specific topics like trigonometry, sets, and polynomials were commonly mentioned as areas where Team work proved effective. Overall, while most students benefited from Team learning, some faced challenges, highlighting both the advantages and difficulties of collaborating in math.

2. What do you like most about studying mathematics? What do you find most challenging?

Students enjoyed studying mathematics for various reasons, including problem-solving, playing with numbers, and finding solutions to equations, especially when working with friends. Many find aspects like trigonometry, algebra, and polynomial calculations particularly engaging, while others appreciated the challenge of solving real-life related problems. However, the most challenging aspects of math for many students were word problems, trigonometry, and certain concepts like exponents, polynomials, and solving for variables like x. Some also find complicated or "trick" questions difficult, and there are those who felt that almost everything in math can be challenging. Despite these difficulties, students enjoyed the satisfaction of finding the right answer and solving complex problems, especially through collaboration and practice.

3. How do you feel about working with your classmates on math assignments?

Many students feel positive and comfortable working with their classmates on math assignments. They enjoyed the collaborative environment, as it helped them learn more and understand concepts better, with many expressing that working together makes problem-solving easier. Phrases like "I feel good," "I feel comfortable," and "I learn more from them" reflect a sense of confidence and satisfaction. Some students also found the experience fun and interesting, while others appreciated the teamwork aspect, which lead to more authentic solutions. Overall, students felt that collaboration not only makes math assignments more enjoyable but also enhances their learning experience.

4. In your opinion, what is the biggest advantage of learning math in a collaborative environment/ team?

The biggest advantage of learning math in a collaborative environment, according to students, is the opportunity to learn from each other and improve skills, which helps in solving real-life problems and understanding concepts more deeply. Many students believed that working together enhances creativity, strengthens problem-solving abilities, and provides a better understanding of mathematical applications, especially in fields like engineering, construction, and business. Additionally, students recognized that collaboration prepares them for future job opportunities, making math an essential skill for career success. The shared learning experience also fosters a brighter future, as math is seen as crucial for many professions and everyday life.

5. How does your attitude toward mathematics change when you work alone versus when you work in a Team?

Students generally reported that their attitude toward mathematics changes significantly depending on whether they work alone or in a Team. When working alone, many feel frustrated, stressed, or even discouraged, especially when they struggle to understand concepts or solve problems. Some students felt bored or weak in their abilities, while others experience frustration and confusion. In contrast, working in a Team boosted confidence, makes problem-solving easier, and enhanced understanding, with many students feeling motivated, supported, and more engaged. Team work helped students learn from each other, making math feel less difficult and more enjoyable, while it also providing a sense of accomplishment when the Team finds solutions together. Overall, students tended to prefer working in Teams for the added support, increased learning, and improved problem-solving ability.

5. Discussions and Conclusion

The analysis of survey data revealed significant demographic and academic trends among the Grade Nine student participants. The majority of respondents were between 13 and 16 years old, with a notable concentration in the 15-year-old age group, signifying a crucial developmental period for targeted academic interventions. The gender distribution within the sample, comprising 50.9% male and 49.1% female students, ensured a balanced representation, thereby minimizing potential gender-based biases in the findings. Academically, the pre-test results indicated that over half of the students scored below 40% in mathematics, underscoring a substantial need for remedial programs and curriculum enhancements to address foundational deficiencies.

Following the implementation of Team-Based Learning (TBL) strategies, a marked improvement in academic performance was observed, with average mathematics scores increasing from 51% to 65%. This significant gain highlights the effectiveness of collaborative approaches in enhancing mathematical skills (Lewis, 2020). TBL, a structured form of small group learning, is widely recognized for its ability to engage students in meaningful active learning, making it a valuable pedagogical tool in secondary education (Darby, 2023). According to Gustafsson (2024), the structured nature of TBL, which includes individual accountability through readiness assurance tests (iRATs) and Team-Based problem-solving (tRATs and application exercises), fosters deeper engagement and promotes the development of both conceptual understanding and computational fluency. Research by Lewis (2020) specifically demonstrated how Team-Based inquiry learning, a form of TBL, improved mathematics content mastery. Furthermore, studies have indicated that TBL can effectively facilitate mathematical reasoning, which is crucial for conceptual understanding. The emphasis on application-focused exercises within TBL modules directly contributes to the development of computational skills by requiring students to apply learned concepts in practical problem-solving scenarios (Flores-Cohaila & Huaman-Espino, 2024).

Students' responses to the attitude survey further revealed diverse perspectives on mathematics and Team-Based Learning. While a substantial 60% of students reported enjoying mathematics, only 68% expressed confidence in their problem-solving abilities. Team-Based Learning was highly valued, with 80% agreeing that it enhanced their understanding. This aligns with broader findings that TBL methods can improve students' achievement and attitudes towards mathematics (Othman, Steen, & Fleet, 2020). However, only 47% felt motivated specifically by working with peers, suggesting that while the benefits of Team-Based Learning are recognized, individual motivation within Team settings can vary. Despite these nuances, mathematics was widely regarded as important for future prospects (85%), and a majority (57%) found it challenging yet rewarding. Opinions were split regarding preferences for individual versus Team work, indicating a need for instructional flexibility. Qualitative insights from classroom observations and open-ended survey responses further emphasized the benefits and challenges inherent in Team learning. Many students found collaborative problem-solving particularly helpful for grasping complex topics such as trigonometry, sets, and polynomials. This aligns with research by Burgess and Roberts (2020) which suggests that TBL's emphasis on peer discussion and immediate feedback facilitates the clarification of concepts and strengthens problem-solving strategies. Teamwork also appeared to boost confidence and motivation, rendering mathematics assignments more enjoyable, and fostering a more positive affective domain towards the subject. Students recognized collaboration as a means to enhance skills, creativity, and preparedness for future careers, highlighting the broader transferable skills developed through TBL (Chang & Lin, 2022). Conversely, some students expressed a preference for independent work, citing issues with teamwork dynamics or a perceived lack of clarity and simplicity in Team settings. These findings suggest that while TBL strategies effectively improve both comprehension and engagement, careful facilitation and Team management are crucial for optimizing its benefits and addressing individual learning preferences (Haidet, Kubitz & McCormack, 2014). Overall, the evidence strongly supports the value of integrating structured Team-based approaches like TBL into the curriculum to address academic challenges and foster a more dynamic and effective learning environment, ultimately enhancing both conceptual understanding and computational skills in Grade Nine learners.

6. Recommendations

Based on the significant improvements in students' mathematical performance and engagement documented in this study, the findings strongly advocate for the adoption of Team-Based Learning (TBL) as a core pedagogical strategy to enhance conceptual understanding and computational skills in Grade Nine learners. The empirical evidence, showing a marked increase in average test scores and positive shifts in student attitudes, provides a compelling basis for recommending that educators integrate the structured TBL framework—with its cycles of individual readiness assurance and collaborative application exercises—into the regular mathematics curriculum. Furthermore, these results urge curriculum developers and policymakers to support this shift by facilitating teacher training and resource allocation, thereby institutionalizing TBL as a transformative, evidence-based approach to address academic underachievement and foster a more dynamic, collaborative, and effective mathematics learning environment across Bhutanese schools.

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