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Cognitive, Motivational, and Pedagogical Factors Influencing Effective Teaching and Learning in Math Education

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Abstract

This action research investigates the effectiveness of pedagogical interventions in enhancing the teaching and learning of trigonometry among fourth-semester Bachelor of Education (B.Ed.) students at Mid-Western University. Recognizing the abstract nature and practical importance of trigonometry, the study sought to address persistent challenges faced by students, including conceptual confusion, lack of engagement, and poor academic performance. The research was conducted using a cyclical action research framework encompassing three phases: identification, planning, and implementation. Initial diagnostic assessments revealed significant gaps in students' understanding of trigonometric identities, graphs, and applications. In response, a series of interventions were implemented, including active learning strategies, formative assessments, visual teaching aids, and repetition of key lessons. Data were collected through pre- and post-tests, classroom observations, student feedback, and teacher reflection journals. Post-intervention results demonstrated substantial improvements in students' academic performance, conceptual clarity, and classroom participation. The findings support the application of constructivist, feedback-oriented, and student-centred pedagogies in mathematics education. The study concludes that systematic, reflective, and evidence-based teaching strategies can significantly improve trigonometry instruction at the higher education level. Moreover, the action research approach facilitated professional growth for the instructor and fostered a more responsive learning environment. This study offers practical insights for mathematics educators and institutions seeking to improve learning outcomes in abstract mathematical domains.

Keywords: Action Research; Active Learning; Formative Assessment

Introduction

Mathematics plays a crucial role in shaping the cognitive and analytical capacities of students across all levels of education. Within the mathematical curriculum, **trigonometry** stands out as a pivotal topic due to its widespread applications in science, engineering, architecture, and daily life. From calculating heights and distances to analyzing waveforms and designing bridges, trigonometry provides foundational tools for real-world problem-solving. However, the effective teaching and learning of trigonometry, especially at the undergraduate level, remains a significant challenge in many institutions, including Mid-Western University in Nepal. Trigonometry is generally introduced during secondary education, but its complexity increases substantially in higher education where students are expected to master trigonometric identities, inverse functions, transformations, and real-life applications. In the **Bachelor of Education (B.Ed.) program,** students encounter these topics again in more abstract forms, often without sufficient scaffolding from prior knowledge. Many struggles with the symbolic and graphical representations of trigonometric concepts, leading to confusion, disinterest, and ultimately poor academic performance (Orhun, 2010).

In the context of Mid-Western University, anecdotal reports and internal assessments suggest that students in the **fourth semester mathematics education course** exhibit difficulties in understanding and applying trigonometric principles. These difficulties are compounded by several factors: (a) the abstract nature of trigonometry, (b) traditional teacher-centered pedagogy, (c) limited access to visual and technological aids, and (d) insufficient formative assessments and feedback mechanisms. These challenges highlight the urgent need to revisit the pedagogical approach used in trigonometry instruction.

Globally, researchers have emphasized the benefits of shifting from lecture-dominated instruction to **student-centered pedagogies** that involve active learning, problem-based tasks, and technology-enhanced environments. For example, Prince (2004) and Hattie and Timperley (2007) argue that students learn more effectively when they engage in constructing knowledge, receiving timely feedback, and applying concepts in practical settings. In trigonometry, the use of visual models, graphing tools, and interactive exercises can significantly help bridge the gap between abstract concepts and concrete understanding (Dündar, 2015).

Despite the growing evidence supporting such pedagogies, these methods have not been widely implemented in many Nepali classrooms due to systemic limitations, including large class sizes, lack of training in active learning methods, and insufficient institutional support. Consequently, traditional modes of teaching—such as rote memorization, formula-based drills, and exam-oriented instruction—continue to dominate. These approaches often fail to address diverse learner needs, foster misconceptions, and disengage students from deeper mathematical thinking.

In this context, **action research** presents a powerful and flexible method for improving instructional practices from within the classroom. Defined as a reflective and cyclical process involving planning, acting, observing, and reflecting, action research enables educators to diagnose specific issues in their teaching context and implement targeted interventions (Carr & Kemmis, 1986). Through this process, teachers are empowered not just as deliverers of knowledge but as researchers and change agents capable of enhancing student outcomes based on real-time evidence.

This study, therefore, employs action research to explore and address the challenges of teaching trigonometry in the fourth semester of the B.Ed. program at Mid-Western University. By identifying students' learning difficulties, designing relevant pedagogical interventions, and systematically evaluating their impact, the research aims to enhance the effectiveness of trigonometry instruction. The interventions will include active learning strategies, increased use of formative assessments, repetition and reinforcement sessions, and integration of visual teaching aids.

In sum, the study is rooted in the belief that effective trigonometry instruction is not only essential for students' academic progression but also for their broader mathematical literacy and professional development. Through the lens of action research, this investigation contributes to the ongoing efforts to localize best practices in mathematics education and promote reflective, evidence-based teaching in higher education contexts

Literature Review

The Role and Significance of Trigonometry in Higher Education

Trigonometry occupies a critical position in the mathematics curriculum of secondary and tertiary education due to its foundational applications in physics, engineering, architecture, and computer science. As a discipline that connects algebraic reasoning with geometric understanding, trigonometry enhances students’ spatial reasoning and analytical problem-solving skills (Dündar, 2015). It serves as a bridge between pure and applied mathematics, making its mastery essential for STEM students.

According to Orhun (2010), one of the key challenges in teaching trigonometry is the abstract nature of its core concepts—such as radian measures, circular functions, and trigonometric identities—which are not intuitively grasped without a concrete understanding of angle, motion, and periodicity. Students often experience a conceptual disconnect between real-world measurements and the symbolic representations they encounter in textbooks.

Pedagogical Challenges in Teaching Trigonometry

Several studies have documented that traditional lecture-based methods are insufficient in addressing diverse learner needs, especially in subjects like trigonometry that require conceptual visualization and higher-order reasoning (Makgato, 2007). Passive transmission of knowledge, focused primarily on formula memorization and rote calculation, fails to engage students or promote deep learning. Dündar (2015) found that pre-service mathematics teachers themselves struggled to solve trigonometric problems when presented in non-standard formats, indicating systemic weaknesses in foundational understanding and instructional approach.

Furthermore, the complexity of trigonometry necessitates prior mastery in algebra, geometry, and functions, making it a cumulative subject that depends on earlier mathematical competence. Weaknesses in foundational topics, when unaddressed, exacerbate students' difficulties in understanding advanced trigonometric applications. This is consistent with Vygotsky's (1978) socio-cultural theory, which emphasizes the importance of scaffolding and building upon existing knowledge through the zone of proximal development (ZPD).

Cognitive and Affective Barriers in Learning Trigonometry

Research shows that mathematical anxiety, lack of motivation, and negative attitudes towards abstract subjects contribute significantly to poor performance in trigonometry (Zakaria & Nordin, 2008). Affective factors often play an underrated role in academic achievement. Students tend to disengage from content that appears disconnected from real-life applications, especially when instruction is limited to abstract symbols without context (Orhun, 2010).

Cognitive load theory also offers an explanation for student struggles. When students are overwhelmed with information—definitions, formulas, graphs, and algebraic manipulations—without appropriate sequencing and visualization aids, their working memory may not be able to process or retain the information effectively (Sweller, 1988). This is especially relevant in trigonometry, which involves multilayered concepts that demand both procedural fluency and conceptual clarity.

Strategies for Effective Trigonometry Instruction

A wide body of literature advocates for active learning approaches to overcome the limitations of traditional teaching. Active learning refers to pedagogical strategies that involve students directly in the learning process through discussions, problem-solving, collaborative projects, and application tasks (Prince, 2004). In mathematics education, this includes techniques like guided discovery, peer tutoring, concept mapping, and the use of manipulatives or dynamic geometry software such as GeoGebra.

For instance, Zakaria and Zain (2007) demonstrated that student-centered approaches, including cooperative learning and real-world application tasks, significantly improved student achievement in trigonometry compared to control groups taught through conventional methods. These findings are reinforced by constructivist theories of learning, which argue that knowledge is actively constructed by learners when they are engaged in meaningful tasks (Piaget, 1972).

Moreover, integrating technology has shown promise in improving trigonometric understanding. Visual simulation tools, interactive graphs, and animated models can reduce abstraction and enhance spatial intuition. Digital platforms allow for immediate feedback, formative assessment, and individualized learning pathways, which align with differentiated instruction principles (Tall, 1996).

Role of Formative Assessment and Feedback

Another important pedagogical factor highlighted in the literature is the role of formative assessment. Formative assessments—such as quizzes, self-checks, peer reviews, and diagnostic tasks-enable instructors to identify misconceptions early and provide timely feedback. Black and Wiliam (1998) emphasized that effective use of formative assessment can significantly raise student achievement when integrated into regular instruction. In trigonometry, this allows for targeted remediation of specific errors in understanding ratios, identities, and graph interpretations.

Furthermore, feedback plays a crucial role in the learning cycle. Hattie and Timperley (2007) classify effective feedback as one that addresses three key questions: "Where am I going?", "How am I going?", and "What's next?". In trigonometry, detailed feedback can help clarify where a student misapplied a formula, misunderstood a graphical transformation, or neglected a key identity, thereby supporting incremental learning.

Importance of Repetition and Reinforcement

The principle of spaced repetition and review is also well-supported in educational psychology. Trigonometric identities and functions require not only comprehension but fluency, which is best developed through consistent practice over time. According to Ebbinghaus's forgetting curve, knowledge retention significantly improves when learning is revisited periodically. This supports the practice of cyclical review, which this action research adopts through lesson repetition and continuous testing.

Action Research as a Framework for Improvement

Action research itself has been widely recognized as a valid method for improving classroom practice (Kemmis & McTaggart, 1988). It allows teachers to become reflective practitioners who identify local challenges, experiment with solutions, and adapt pedagogy based on observed outcomes. In the context of trigonometry instruction, action research offers a structured yet flexible approach to diagnose instructional barriers and implement iterative interventions.

Carr and Kemmis (1986) argue that action research strengthens the professional agency of teachers while anchoring improvements in real-time classroom realities. This cyclical model of planning, acting, observing, and reflecting enables responsive pedagogy and promotes sustained improvement.

Objectives of the Study

The overarching objective of this action research is to enhance the effectiveness of trigonometry instruction in the fourth semester of the Bachelor of Education program at Mid-Western University through targeted, data-driven interventions.

The specific objectives are: to identify key challenges faced by students in learning trigonometry, including conceptual, procedural, and motivational barriers, to design and implement pedagogical interventions—such as active learning strategies, lesson repetition, formative assessments, and counseling sessions—that address the identified challenges, to evaluate the impact of these interventions on student learning outcomes, including comprehension, engagement, and academic performance, and to reflect on the instructional process and propose sustainable teaching strategies that can be integrated into future mathematics education practices.

Methodology

This study employed an action research methodology to enhance the effectiveness of trigonometry instruction for fourth-semester Bachelor of Education (B.Ed.) students at Mid-Western University. Action research was chosen because it allows educators to identify classroom-specific problems, implement context-relevant interventions, and reflect critically on their teaching practices (Carr & Kemmis, 1986). The research followed **a** cyclical process of planning, acting, observing, and reflecting**,** making it ideal for continuous instructional improvement in real-time settings.

Research Design

The study adopted a qualitative-dominant mixed-methods design**,** integrating both qualitative and quantitative data to gain a comprehensive understanding of teaching challenges and intervention outcomes. The research was structured into three main phases:

Identification Phase **–** Diagnosis of the key learning challenges faced by students**.**

Planning Phase **–** Design of pedagogical interventions based on identified issues.

Implementation Phase – Application of interventions, followed by observation and analysis of their impact.

Participants

The participants consisted of 35 B.Ed. fourth-semester students enrolled in the trigonometry course at Mid-Western University, along with the course instructor (researcher). The sample was selected purposively, focusing on one intact classroom to allow for manageable intervention and detailed observation. Students' prior academic records and diagnostic tests were used to assess baseline performance and group-level readiness.

Data Collection Tools and Procedures

Multiple tools were employed to collect data throughout the research cycle:

Diagnostic Test*:* Administered at the start of the semester to identify baseline knowledge and common misconceptions.

Classroom Observation*:* Conducted during regular instruction to examine student engagement, participation, and instructional flow.

Formative Assessments*:* Regular quizzes and problem-solving exercises were used to monitor progress and guide instructional adjustment.

Student Feedback Forms*:* Collected anonymously to understand learners' perspectives on instructional strategies, clarity, and confidence.

Teacher Reflective Journal: Maintained by the researcher to document teaching strategies, classroom responses, and personal insights after each session.

Data Analysis

Quantitative data (test scores and quiz results) were analyzed using **descriptive statistics** (mean, median, and percentage improvement) to evaluate academic gains before and after intervention. Qualitative data (observation notes, feedback forms, and journals) were analyzed thematically to identify patterns in student engagement, learning attitudes, and teaching effectiveness.

Ethical Considerations

Informed consent was obtained from all student participants. Anonymity and confidentiality were maintained in the reporting of results. The study adhered to the ethical guidelines set by the research unit of Mid-Western University.

Findings

This section presents the results of the action research conducted to enhance the teaching effectiveness of trigonometry among fourth-semester Bachelor of Education students at Mid-Western University. Findings are organized according to the research phases—**diagnostic/identification, intervention/implementation,** and **reflection—**and are drawn from multiple data sources, including diagnostic tests, formative assessments, classroom observations, student feedback, and teacher reflections.

Identification Phase: Diagnostic Insights

The initial diagnostic test was administered to all 35 participating students to assess their baseline understanding of core trigonometric concepts, including angle measurement, trigonometric ratios, identities, and applications. The test revealed several key deficiencies:

Low conceptual understanding: Only 22.8% of students correctly applied sine and cosine rules, indicating confusion between ratios and identities.

Limited procedural fluency: 65.7% of students could not solve problems requiring transformation or manipulation of trigonometric identities.

Poor retention of prior knowledge: Many students lacked the prerequisite knowledge of geometry and algebra necessary for advanced trigonometry.

Classroom observations further confirmed these findings. Students appeared hesitant to participate in discussions, and their written responses showed gaps in reasoning and symbolic manipulation. Teacher-student interactions were largely unidirectional, with minimal feedback loops. These observations validated the need for a shift toward more

interactive, scaffolded, and student-centered teaching strategies.

Planning and Implementation Phase: Intervention Outcomes

Following the diagnostic stage, a structured set of interventions was introduced over a 6-week period. The teaching strategies were based on **active learning principles, frequent formative assessment**, and **repetition with variation.**

Improvement in Academic Performance

Quantitative data from regular formative assessments and a final summative test showed marked improvement in students' academic performance:

Assessment Stage	Average Score (%)
Pre-Intervention Test	41.4
Mid-Term Formative Avg	58.7
Post-Intervention Test	73.2

The **31.8% increase** from the baseline to the final assessment indicated that the instructional interventions significantly improved students' comprehension and problem-solving abilities. Specific gains were observed in:
Understanding of trigonometric identities (increase from 35% to 75% correct responses),
Use of unit circle and graphs (from 20% to 66%),
Application-based problems (from 29% to 68%).

Engagement and Participation

One of the most notable changes was in **student engagement.** Through group activities, peer instruction, and problem-solving workshops: 85% of students actively participated in class compared to only 43% before intervention. 29 students reported increased **confidence** in solving trigonometry problems in a post-intervention feedback form. Group work and visual aids (like GeoGebra and paper trigonometric circles) helped demystify abstract ideas and fostered collaborative learning.

Observation logs indicated a **more dynamic classroom environment,** with students asking questions, correcting one another, and engaging in productive struggle. The teacher's role shifted from a content deliverer to a facilitator of inquiry.

Impact of Formative Feedback

Frequent, low-stakes quizzes and personalized feedback helped identify learning gaps in real time. Students appreciated feedback that clarified **why** an answer was incorrect rather than simply marking it wrong. According to open-ended responses:

“The continuous feedback helped me know my mistakes and fix them quickly.” – Student Feedback Form

“Earlier I used to memorize formulas, but now I understand when and why to use them.”

– Student Reflection

Such responses reinforce the importance of **feedback-rich instruction** in developing deeper mathematical understanding, as supported by Hattie & Timperley (2007).

Repetition and Reinforcement

The strategic use of **repetitive review sessions** proved particularly effective for long-term retention. Key identities, formulas, and graphing techniques were revisited weekly using varied examples and modalities. This spaced reinforcement enabled better consolidation of knowledge: Students who previously scored below 40% on identity-based problems improved by an average of 35 percentage points. Those attending counseling and reinforcement classes performed 22% better than their peers on average.

Reflection Phase: Qualitative Insights

Reflections gathered from both students and the teacher provided rich qualitative data. Key themes that emerged include:

a) Positive Shift in Attitude Toward Trigonometry: Student responses revealed a significant shift in mindset. “I used to fear trigonometry, but now it feels logical.” “Group work made it easier to ask questions without hesitation.” “Using graphs and real examples made it interesting.” This attitudinal transformation is a critical outcome, as mathematics anxiety and negative perceptions often act as barriers to success (Zakaria & Nordin, 2008).

b) Professional Growth for the Teacher: The research process also led to substantial professional development for the instructor. The reflective journaling practice highlighted several shifts: Increased awareness of **student misconceptions** and their underlying causes. Improved skill in **designing differentiated instruction.** Enhanced capacity to balance **content delivery with conceptual understanding.** Moreover, the action research cycle fostered a **collaborative learning environment,** as the teacher engaged in co-learning with students rather than unidirectional instruction.

c) Challenges Encountered: Despite positive outcomes, some challenges were encountered: Time constraints. Additional reinforcement and feedback sessions demanded more instructional hours than the standard curriculum allowed. Resource limitations: Access to digital tools like GeoGebra was not uniformly available to all students, requiring blended teaching approaches. Diverse readiness levels: Some students continued to struggle despite repeated interventions, highlighting the need for more personalized, long-term support. These challenges underline the importance of **institutional support** and flexible planning in sustaining pedagogical innovation.

Significant academic gains were observed after intervention, with a 31.8% average improvement in test scores. Engagement levels doubled, and students expressed higher confidence and interest in trigonometry. Formative feedback and repetition emerged as critical tools for supporting conceptual understanding. Students responded positively to visual and interactive teaching methods, such as graphing tools and group work. The action research cycle contributed to professional growth and a more reflective, responsive teaching approach.

Overall, the findings demonstrate that well-planned, context-sensitive instructional strategies can transform the learning experience in trigonometry, even in resource-limited settings. The study not only improved immediate student outcomes but also provided a replicable model for ongoing instructional improvement through action research

Discussion

The findings of this action research reveal that targeted pedagogical interventions can significantly improve the teaching and learning of trigonometry in the Bachelor fourth-semester classroom. These outcomes are consistent with several well-established educational theories, particularly those emphasizing active learning, formative feedback, constructivist learning environments, and reflective teaching practices. This discussion will explore the implications of the findings through the lens of relevant theories and global research on mathematics education.

Active Learning and Constructivist Theory

The dramatic increase in student engagement and performance following the implementation of **active learning strategies** aligns closely with **constructivist learning theory,** particularly the work of Piaget (1952) and Vygotsky (1978). Constructivists argue that learners actively construct their knowledge based on experiences, rather than passively receiving information. When trigonometric concepts were introduced through problem-solving tasks, collaborative group work, and visual models, students were no longer passive recipients of formulae but active agents in constructing mathematical meaning.

Vygotsky's (1978) concept of the **Zone of Proximal Development (ZPD)** is especially relevant. Many students initially lacked the independent capacity to solve complex trigonometric problems. However, with the help of scaffolding—through peer collaboration, teacher guidance, and visual aids—they operated within their ZPD and achieved higher levels of understanding. This supports the use of **socially mediated learning** in mathematics classrooms, particularly when tackling abstract content such as trigonometric identities and graphs.

Formative Assessment and Feedback

The role of **frequent formative assessment and feedback** in improving student outcomes is well documented in the literature. Hattie and Timperley (2007) assert that feedback is one of the most powerful influences on student achievement, particularly when it is timely, specific, and focused on the learning process. In this study, the introduction of regular quizzes and personalized feedback helped students identify their learning gaps and make immediate corrections.

From a theoretical perspective, this aligns with **Black and Wiliam's (1998)** model of formative assessment, which emphasizes the integration of assessment into the learning process. Students responded positively to feedback that clarified misconceptions rather than merely judging correctness. This shift from summative to formative thinking helped build a **growth mindset,** where errors were seen as opportunities for learning rather than failure. Carol Dweck's (2006) theory supports this finding, arguing that students with a growth mindset are more likely to persist in the face of academic challenges.

Cognitive Load and Scaffolding

The significant gains in students' ability to solve trigonometric problems after lesson repetition and strategic scaffolding suggest a reduction in **cognitive load**. According to Sweller's (1988) **Cognitive Load Theory,** students struggle to learn complex material when their working memory is overwhelmed. Trigonometry often involves symbolic manipulation, spatial reasoning, and connections across multiple domains—geometry, algebra, and real-world applications—which can place a high cognitive demand on learners.

By breaking down complex concepts, sequencing instruction effectively, and integrating visual aids (such as graphs and the unit circle), the teaching strategies helped **manage intrinsic and extraneous cognitive load.** These techniques enabled deeper processing and long-term retention, especially among students who previously struggled with abstract reasoning.

Mathematics-Specific Pedagogical Insights

In mathematics education literature, Boaler (2016) advocates for **mathematical mindsets** that emphasize understanding, flexibility, and creative problem-solving rather than rote memorization. The results of this action research affirm Boaler's position: once students were encouraged to explore patterns, visualize functions, and collaboratively solve problems, their interest and confidence improved markedly.

Additionally, the inclusion of visual representations and real-world connections—although limited by resources—played a crucial role in **bridging abstract concepts to tangible understanding.** This is consistent with the **dual coding theory** (Paivio, 1986), which suggests that information is better retained when verbal and visual modalities are combined. Students exposed to both symbolic and graphical representations of trigonometric functions demonstrated stronger conceptual clarity.

Reflective Teaching and Action Research

Finally, this study validates the **action research model** as an effective tool for improving instructional practices in higher education. As Carr and Kemmis (1986) explain, action research fosters a culture of **critical reflection and continuous improvement,** empowering teachers to become agents of change in their classrooms.

Through journaling, observation, and student feedback, the instructor in this study adapted instructional strategies in real-time. This flexible and iterative approach not only improved student learning but also enhanced the teacher's professional development. Such reflective practice aligns with Schön's (1983) model of the **reflective practitioner,** which is vital for sustainable change in education.

Implications and Broader Relevance

The success of these interventions holds important implications for other classrooms and institutions, particularly in developing country contexts like Nepal where resource limitations and exam-oriented curricula dominate. Even with modest tools—peer learning, repetition, feedback, and conceptual visuals—substantial gains in student learning can be achieved. Moreover, this study advocates for a **bottom-up reform** approach in mathematics education, where teachers innovate within their classrooms and inform broader curriculum policy through evidence-based practices.

Conclusion

This action research was undertaken to improve the effectiveness of trigonometry instruction for fourth-semester Bachelor-level students at Mid-Western University. The findings demonstrate that strategic interventions—such as active learning strategies, lesson repetition, formative assessments, and use of visual teaching aids—can significantly enhance students' conceptual understanding, engagement, and academic performance in trigonometry.

The pre-intervention diagnostic assessments revealed substantial gaps in students' procedural fluency and conceptual clarity. Post-intervention data, however, showed marked improvements in both test scores and student attitudes. Students reported greater confidence, deeper comprehension, and a more positive disposition toward learning mathematics. These outcomes validate the application of constructivist and learner-centered pedagogies in the teaching of abstract mathematical content like trigonometry.

Moreover, the research experience itself fostered professional growth for the teacher-researcher. The use of reflective journaling, real-time adaptation of strategies, and student feedback enabled a more responsive, engaging, and effective classroom environment. The study reinforces the value of action research as a practical model for continuous improvement in teaching and learning, particularly within resource-limited and exam-oriented academic systems like those found in Nepal.

Ultimately, the success of this study shows that when teaching is informed by both theory and classroom-based evidence, even traditionally difficult subjects like trigonometry can be taught more effectively, leading to improved learning outcomes and a more empowering experience for students.

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