

Editorial

Integrating Technology in Mathematics Education: Expanding a Boundary of Transformative Learning

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Abstract

Mathematics education evolves in conjunction with human civilization, scientific inquiry, technological advancements, and ontological-epistemic practices. This editorial examines five distinct yet interconnected research studies that collectively support the advancement of our understanding of effective mathematics education. Through examining 3D visualization technologies in differential geometry, teacher agency within centralized curriculum reforms, the psychological construct of mathematics self-efficacy, the historical evolution of summability methods, and metacognitive awareness across linguistic contexts, we illuminate the multidimensional nature of mathematics education research. These studies have employed diverse methodological traditions, ranging from design-based research and narrative inquiry to systematic reviews and historical analysis, to illuminate how technological pedagogical content knowledge, transformative praxis, and learner-centered approaches contribute to enhancing mathematical understanding. The synthesis features that meaningful mathematics learning emerges through the integration of technology with carefully orchestrated experiences that develop students' cognitive schemas, teachers' professional knowledge and skills, and the historical development of the disciplines. In this context, this editorial calls for the continued integration of technology-enhanced visualization to empower teachers and students' learning agency, cultivate learner self-efficacy for developing an engaged learning culture, and develop metacognitive competencies as essential components of transformative mathematics education.

Keywords: Technological pedagogical content knowledge, 3D Visualization, Teacher agency, Mathematics self-efficacy, Metacognitive awareness

Introduction

Mathematics education is nothing but the product of human civilization, along with scientific inquiry, technological advancements, and onto-epistemic practices.

However, the contemporary pedagogy in mathematics education seemed to be dominated by a transmissionist approach, in which teachers tried to deposit mathematical knowledge, concepts, and theorems into learners' heads without considering the background of the learners. It has not created a deeply engaged learning environment in which learners get enough opportunities for conceptual, relational, cultural, and critical understandings of subject matters taught in schools and universities (Lamichhane et al, 2023). To liberate mathematics education from this disempowering notion of pedagogy, it is necessary to integrate dynamic visualization tools, to recognize learners as cognizing beings, to consider non-cognitive aspects of learners— affective, emotional, and spiritual, and to appreciate a social, cultural, and historical path of mathematical development (Lamichhane & Luitel, 2023), because these attributes significantly influence mathematics learning, mathematical achievement, and cultivation of metacognitive awareness (Dahal et al., 2022; Luitel & Dahal, 2020). Moreover, these attributes shape how students experience, internalize, engage, and navigate the learning process across diverse educational contexts.

In this regard, the five research studies included in this issue of the Mathematics Education Forum Chitwan (MEFC) signify distinct yet complementary perspectives of mathematics education research. The first study examines how three-dimensional visualization technologies support the illustration of complex concepts related to tangent and normal planes and their features in Differential Geometry. It also effectively demonstrates the roles of Technological Pedagogical Content Knowledge (TPACK) frameworks in teaching and learning activities in higher geometry, supporting the enrichment of learners' good learning experiences (Guerrero, 2010; Koehler & Mishra, 2009). The second investigation employs William Pinar's *Currere* approach of curriculum development as a theoretical lens to explore how secondary mathematics teachers in Nepal navigate centralized curriculum reforms, revealing tensions between systemic constraints and professional agency (Pinar, 2012). The third article explores the roles of students' mathematics self-efficacy through a systematic literature review and synthesizes the evidence on how students' self-efficacy beliefs affect mathematics learning outcomes (Bandura, 1997; Pajares & Graham, 1999). The fourth study traces the historical evolution of Euler's summability method for infinite series, its epistemological roots, and attempts to connect contemporary mathematical discourse (Euler, 1748/1988). Finally, the fifth article examines the roles of language of instruction for the development of metacognitive awareness among secondary-level

students in learning (Sperling et al., 2002). This issue of MEFC illuminates contemporary mathematics education research practices—from individual self-efficacy cognitive processes to institutional structures underpinning the curriculum development, from historical roots of mathematical foundations to technological integration, and from local pedagogical practices to universal learning principles. In this context, we have attempted to synthesize key insights from the five articles included in this issue, aiming to identify emerging themes that warrant continued scholarly attention.

Technological Pedagogical Content Knowledge and 3D Visualization

The integration of three-dimensional visualization technologies in pedagogical practices in mathematics education supports presenting abstract mathematical concepts in a visually dynamic form. It enhances a conceptual understanding of the subject matter taught at school and university levels because it demonstrates the abstract mathematical concepts in a visual dynamic form, supporting the higher-order cognitive schemas (Tall, 1992). Dhakal (2025 in this issue) revealed three crucial outcomes of the integration of three-dimensional visualization—formulation of cognitive schemas as mental images, improvement in conceptual understanding, and sustained attention and motivation toward engaged learning. In doing so, the dynamic visualization tools such as GeoGebra, Cabri 3D, Mathematica, Matlab, etc. facilitate connecting the mathematical concepts with real-world problems (Guyen, 2012; Mainali & Key, 2012; Lamichhane et al., 2023).

Moreover, employing 3D-visualization successfully helps explore the mathematical structure, its meaning, and implications for solving real-world problems. Likewise, Dhakal (2025, in this issue) highlights the TPACK as a theoretical framework for navigating the research in mathematics education and illustrates the necessity to develop knowledge and skills on how technological, pedagogical, and content knowledge integrate synergistically for effective implementation of technology in the mathematics classroom (Mishra & Koehler, 2006). It reflects that teaching is not simply a technical and mechanical activity to disseminate mathematical information to learners, but rather it is a process of engaging the learners in the learning process by fostering creative, innovative, and imaginative thinking and reasoning (Gaisman et al., 2018). The TPACK emphasizes that teachers must become orchestrators in which they have specific content and pedagogical knowledge along with technological skills so that they have good skills of how and when to introduce visualization, which technology is appropriate

for enhancing the conceptual understanding, how to scaffold exploration process, and ways of engaging in reflective activities (Ozudogru & Ozudogru, 2019) that makes mathematics classroom more engaging, livelier and meaningful. It signifies that the 21st-century mathematics teachers must have the knowledge and skills of emerging technologies, including augmented reality, virtual reality, and artificial intelligence-enhanced adaptive systems (Kaufmann, 2009), to foster the creative, innovative, and imaginative thinking and reasoning for solving the complex, emerging real-world problems so that learners become autonomous and responsible learners.

Teacher Agency and Curriculum Reform Through Currere

While technological affordances expand possibilities for learning through an active engagement in the learning process in which teachers play the role of orchestrator, as more knowledgeable others to scaffold the learning process rather than depositing the mathematical contents into the learners' heads (Freire, 1993). However, these possibilities depend fundamentally on teacher agency within the immediate environment and institutional contexts. In this context, Ghimire (2025 in this issue) explores the status of the teachers' agency through the narrative inquiry in the context of centralized curriculum reform in Nepal. It reveals profound tensions between systemic structures and teachers' professional identities. He employs William Pinar's Currere as an autobiographical approach that progresses through regressive, progressive, analytical, and synthetic phases. The study captures the lived experiences of four mathematics teachers in the context of the Tylerian objectives-based curriculum development model (Pinar, 2012; Tyler, 1949).

The Tylerian approach dominates in Nepal's centralized education system, emphasizing predetermined objectives, standardized content sequences, and an assessment of learning approach to measure learning outcomes that leaves no space for teachers to act as autonomously responsible agents to implement their signature pedagogical approaches in the mathematics classroom for the betterment of teaching-learning activities. Teachers' narratives reveal complex negotiations rather than simple compliance or resistance, in which they can only do their routine duties. The highly centralized and systemic dominating structures of curriculum development and implementation approach urges the teachers and students as well to adopt the learning by doing as an unquestionable without consideration of its impacts, moral values and imperative that restrains the transformative praxis (Luitel & Dahal, 2020), thereby

developing the images of curriculum as cultural reproduction, silos of discrete contexts, rather than curriculum as social reconstruction and currere (Schubert, 1986; Luitel, 2009; Lamichhane, 2020). The study identifies four intricately intermingled challenges: erosion of curriculum development roles, navigating socioeconomic disparities that affect student achievement, confronting pedagogical crises in compulsory mathematics education, and resisting political interference in school governance. These challenges emerge not as isolated problems but as interconnected effects of rigid curriculum structures that fail to honor teacher expertise. It opens a productive avenue for discourse that teachers' subjective experiences and roles of agency need to be incorporated within policy dialogue and the curriculum development process, which were and still are typically dominated by objective metrics and standardized outcomes.

Mathematics Self-Efficacy and Academic Achievement

The paper in this issue by Dahal and GC raises the issue of self-efficacy and its relation to academic achievement. Mathematics self-efficacy (MSE) is nothing but students' beliefs and level of confidence in their ability and capability to perform mathematical tasks independently and successfully, which has profound and powerful impacts on achievement, motivation, and persistence (Bandura, 1997). The issue of achievement is one of the most discussed issues in Nepali mathematics education. The National Assessment of Student Achievement (NASA) has explored that students' achievement in mathematics is below average, and students have not performed well in higher-order cognitively demanding tasks (ERO; 2020). Likewise, students do not seem to be confident in solving mathematical problems and remain indifferent in their learning; however, there is a rare discussion on the role of self-efficacy in mathematics teaching-learning activities. In this context, Dahal and GC (2025 in this issue) examine the mathematics self-efficacy through a systematic review of twelve peer-reviewed articles published between 2019 and 2025. They have employed PRISMA-ScR guidelines to ensure methodological rigor in this paper.

The authors have identified five interconnected themes that characterize the relationship between MSE and achievement. Firstly, they explored the significant roles of mathematical tasks endorsed in mathematics classrooms and multidimensional instructional practices in the formulation of self-efficacy in mathematics education. Secondly, a review of longitudinal research studies revealed the impact of past experiences and achievement in mathematics on developing mathematics self-efficacy.

Thirdly, efficacy and performance could be reinforced in the targeted interventions, including mastery-oriented instruction, appreciative pedagogy, and the use of dynamic visualization tools such as GeoGebra, Mathematica, MATLAB, etc. Fourthly, the authors revealed a link between MSE and achievement, which is influenced by mediating and moderating factors such as cognitive ability, interest, anxiety, gender, and socioeconomic background of the learners. Lastly, this study explored the contextual differences of formulating and self-efficacy and its impact on teaching-learning activities. It signifies that the positive mathematics self-efficacy greatly influenced the students' achievement and might also mitigate the systemic disparities in mathematics. Likewise, this highlights that teachers and other concerned authorities need to be aware that there is no royal road to developing the mathematics self-efficacy, but it is highly dependent on contexts, students' background, and pedagogical approach. An understanding of self-efficacy beliefs in a generic form is insufficient for understanding mathematical learning because students may exhibit confidence in algebra while doubting their abilities in geometry, or vice versa. Moreover, longitudinal evidence indicated a bidirectional relationship between self-efficacy and performance. Notably, prior achievement in mathematics has profound and critical impacts on subsequent self-efficacy. This finding suggests that searching for simplistic and generic intervention models for improving the level of self-efficacy that automatically improves achievement is awkward because self-efficacy influences performance, while the relationship operates through complex mediating processes (Pajares & Miller, 1994).

Historical Perspectives: Euler's Summability and Infinite Series

In this issue, Paudyal has explored the historical development of Euler's summability of infinite series. It examines Euler's summability methods for infinite series—including his famous solutions to the Basel problem and treatments of Grandi's series. Leonhard Euler's groundbreaking work on divergent series in the 18th century laid the foundations for contemporary summation methods, which appear in some modification in the present day and become popular by various names such as Cesàro, Abel, Hölder, Nörlund, Hausdorff, and Borel summation (Euler, 1748/1988; Kline, 1972).

Euler claimed that divergent series could have definite values, which became controversial initially. His solution to the Basel problem becomes a groundbreaking achievement in mathematics (Dunham, 1999). The problem, first posed by Pietro

Mengoli in 1650, had not had a solution for decades before Euler's brilliant solution in 1734. It had not been recognized and rigorously justified by the lens of the 18th-century standard. However, it imprinted a profound insight among infinite series, trigonometric functions, and fundamental constants. Similarly, Euler's treatment of Grandi's series ($1 - 1 + 1 - 1 + \dots$) significantly contributed to the development of the concept of conditional convergence and alternative summation methods. At the same time, there was a general convention among the mathematicians that the series lacks a sum, because the partial sums of the sequence of the series oscillate between 0 and 1 indefinitely. Euler assigned the value $1/2$ based on regularization techniques. Initially, it becomes seemingly paradoxical; however, in the later phases, it proves consistent with various generalized summation methods and connects to modern concepts in analytic continuation and regularization theory (Hardy, 1949).

The Euler-Maclaurin summation gives the sums by using integrals that facilitate numerical computation and theoretical analysis across mathematics and physics. It supports finding the sums of the series by correcting the terms. It helps illustrate how Euler's contribution remains essential in contemporary mathematical discourse, with remarkably divergent infinite series. Its derivation and application in different branches of mathematics has established a sophisticated interplay between discrete and continuous mathematics, a central theme of mathematical analysis. In this regard, it offers several benefits to practitioner researchers, mathematicians, and mathematics educators. First, it explores how mathematical knowledge has been developing through human inquiry across different civilizations. Second, historical inquiry highlights that mathematics is a culturally embedded discipline rather than a purely abstract discipline, as Euler's work emerged from specific contexts of the intellectual environment of 18th-century Europe. Finally, it provides a foundation for engaging in mathematical exploration.

Integrating historical perspectives into contemporary mathematics curricula and discourse requires thoughtful pedagogical engagement, rather than presenting historical facts or information as additional content to already crowded curricula, and cannot bring a transformative shift in mathematics education. However, using historical perspectives to explore the contemporary academic discourse employing historical problems as exploratory tasks, discussing historical controversies to highlight conceptual subtleties, and analyzing how notation and representations evolved can genuinely enhance learning (Tzanakis & Arcavi, 2000). The research article by Paudyal in this issue is an initiation

to explore the Euler study, implicitly inviting scholars to engage with it critically, and offers pedagogical applications by documenting the evolution of the summation method.

Metacognitive Awareness and Language of Instruction

The final article in this issue, Paudel and Ghimire have raised the issue of the language of instruction for the development of metacognitive awareness. Metacognition is a state of awareness and regulation of one's own thinking and reasoning that has a significant effect on mathematical competence and learning. Metacognitive awareness supports the learners to monitor their comprehensive learning approach, evaluate the effectiveness of strategies the learners have employed to solve the problems, and guide them to adjust the employed strategies when the initial attempts have failed to generate the required solution (Schoenfeld, 1992). Students with strong metacognitive thinking, reasoning, and skills have a better ability and capability to understand complex problems, explore the interconnectedness and structure of mathematical problems, identify sources of confusion, select appropriate strategies, and persist through difficulty than peers with weaker metacognitive awareness. In this context, authors try to explore whether the language of instruction in secondary level mathematics classrooms—Nepali versus English affects the metacognitive development or not. They have employed the Junior Metacognitive Awareness Inventory with 402 ninth-grade students across six schools in the Kathmandu Valley. This research study has revealed a relatively high average score of metacognitive awareness (Mean = 66.254) of the students who were taught in the Nepali medium of instruction, as compared to their counterparts who were taught in the English medium of instruction, with considerable individual variation. However, the difference has not proved to be statistically significant ($p = 0.237$) at the 0.05 level of significance.

The findings of the study suggest that the language of instruction in the mathematics classroom may not have a significant impact on metacognitive development. This study has opened a new discourse in the field of the language of instruction that can hold a particular significance in multilingual contexts, such as Nepal, where educational policy debates often focus on whether instruction should be conducted in local languages or international languages like English. More specifically, it contradicts the general arguments put forward by the proponents of mother-tongue instructional activists. They have continuously argued that conceptual and relational understanding in any discipline, either in social and natural sciences, develops more

readily when students are taught in their native language (mother tongue). Meanwhile, advocates of English as a medium of instruction in schools and universities emphasize access to opportunities in the 21st-century complex global marketplace. In this regard, this research illustrates the necessity of longitudinal substantial research to resolve the debates on this issue.

Longitudinal research tracking metacognitive development across schooling—private, communal, and governmental, and combined quantitative and qualitative investigations of how different instructional approaches in various linguistic contexts support developing metacognition of the students, which would strengthen the research findings and can be generalized. Additionally, examining metacognitive awareness across mathematical domains—Arithmetic, Algebra, Geometry, Statistics, Probability—could reveal whether language effects vary by content type. Indeed, teachers who emphasize the metacognitive development process need to structure the mathematical tasks that require self-monitoring, self-regulation, and questioning on the thinking process for fostering metacognitive awareness, regardless of the instructional language in the classroom. It helps develop the questioning power of the learners to themselves such as what am I trying to find, what strategies might work, do our solution make sense, and are there any alternative ways of solving the problems that require explanations of reasoning rather than solely getting solution of the problem and providing structured reflection opportunities, that explicitly enhances both metacognitive awareness and achievement outcomes (Kramarski & Mevarech, 2003). An effective approach includes teaching students to ask themselves questions while solving problems. Creating classroom cultures where thinking becomes visible, where students regularly articulate and evaluate their reasoning, and where self-regulation receives explicit attention will support metacognitive development regardless of whether instruction occurs in Nepali, English, or any other language.

Concluding Remarks

The studies featured in this issue illustrate emerging research operating across different fields of mathematics education. It ranges from the development of individual cognitive capability supported by 3D visualization to institutional structures contributing to shape teacher agency, from psychological constructs that mediate achievement to historical developments that illuminate contemporary practice, and from metacognitive competencies that transcend linguistic contexts to systematic reviews of the self-efficacy beliefs of learners. These research articles collectively advance our understanding of

how diverse research traditions—design-based research, narrative inquiry, systematic review, historical analysis, and quantitative survey contribute essential insights.

For practitioners, these studies suggest that effective mathematics education requires attention to multiple dimensions simultaneously. Integrating powerful technologies without having sound pedagogical and content knowledge seems to be insufficient to bring the expected shifts in mathematics education. Similarly, the existing curriculum, its aligning pedagogical activities, and institutional structures in which power imbalance might limit teacher agency because teachers do not get an opportunity to work autonomously. Likewise, high-quality content instruction that ignores students' self-efficacy beliefs and metacognitive development leaves many learners behind, despite having technically competent teaching. Moreover, historical and epistemological sensitivity without due attention to the contemporary learning environment and needs and aspirations of learners might risk becoming antiquarian and irrelevant. It signifies that for the overall betterment of mathematics education, it requires considering integrating an advanced technology with sound pedagogy and content knowledge, developing the teachers' professionalism, making an accountable institutional structure, addressing the cognitive challenge of learners, becoming mindful of historical development and responsiveness, and being conscious of contemporary research and practices. This integrative vision animated the transformative praxis in mathematics education (Luitel & Dahal, 2020), which emphasizes how genuine educational transformation emerges through deep dialogical engagement among multiple perspectives rather than privileging a particular aspect.

In this regard, Mathematics Education Forum Chitwan continues its mission of advancing mathematics education research and practices through publishing diverse, rigorous, and practically pertinent scholarship. The research articles included in this issue illuminate this commitment by offering insights that deepen theoretical, philosophical, and technological understanding that contribute to practical improvement. Finally, we would like to invite the mathematics education community to engage critically with these works, to expand the findings through rigorous and large-scale research projects that support translating these findings into implications for enhancing the existing teaching-learning practices. Through such collective effort, mathematics education can develop to its potential, thereby opening a new avenue that might contribute to transforming existing mathematical education to be more inclusive, which would create just educational futures.

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