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Integrating Popular Digital Contexts into Realistic Mathematics Education: Designing a Hypothetical Learning Trajectory for Arithmetic Sequences and Series

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Abstract

The integration of popular culture and digital platforms into mathematics learning remains underexplored, limiting the development of meaningful and context-based instructional designs. This study develops a Hypothetical Learning Trajectory (HLT) for arithmetic sequences and series by integrating TikTok into a digital mathematics classroom. The study was conducted within the preliminary design phase of design research using qualitative methods, including literature review, classroom observations, teacher interviews, and expert validation through focus group discussions. The resulting HLT consists of two iceberg models grounded in the principles of Realistic Mathematics Education (RME). Each model contains six sequential activities comprising one contextual situation and five guided mathematical problems. The first model employs viewer-growth data from the TikTok account @raimlaode94 to support students in constructing the arithmetic sequence formula (Un) through repeated addition and ratio tables. The second model uses engagement data from the TikTok account @jeromepolin98 to guide students in deriving the arithmetic series formula (Sn) using structured tables, ratio columns, and visual folding strategies. Both trajectories are collaboratively implemented using Canva to maximize the pedagogical use of digital devices. This study provides a theoretically grounded and scalable framework that connects students' informal digital experiences with formal mathematical reasoning in technology-enhanced classrooms.

Keywords: Arithmetic sequences and series; Rigital classrooms; Hypothetical learning trajectories; Popular contexts; Realistic mathematics education; TikTok

Introduction

The rapid integration of digital technologies into secondary education has accelerated the implementation of digital classroom program across diverse educational contexts worldwide. In Indonesia, initiatives such as the Year 11 digital classroom program in Kolaka Regency exemplify this transformation by equipping students with tablets, smartboards, and internet connectivity to support technology-enhanced learning. Despite these infrastructural advancements, preliminary classroom observations indicate that mathematics instruction frequently remains pedagogically conventional. Teachers often underutilize interactive digital platforms and collaborative applications, resulting in digital classrooms that merely replicate traditional instructional practices rather than leveraging technology to enhance mathematical reasoning, visualization, exploration, and student-centered inquiry. This condition underscores the urgent need for innovative instructional designs capable of aligning digital infrastructure with theoretically grounded and pedagogically effective learning frameworks.

One promising approach for addressing this challenge is the Hypothetical Learning Trajectory (HLT), which conceptualizes learning as a systematically designed progression from informal understanding toward formal mathematical reasoning through sequenced activities, anticipated student thinking, and reflective discourse (Sztajn et al., 2012). Within digitally mediated environments, HLTs have considerable potential to support the visualization of abstract mathematical relationships, exploratory problem solving, and collaborative modelling through interactive technological platforms (Can, 2020; Cirneanu & Moldoveanu, 2024). Moreover, comparative studies demonstrate that digitally supported learning trajectories contribute significantly to students' conceptual understanding and procedural fluency when compared with conventional instructional approaches (Clements & Sarama, 2024). Nevertheless, the effectiveness of such trajectories depends not solely on access to digital technology, but also on the careful selection of meaningful contexts that correspond to students lived experiences and cognitive entry points.

Arithmetic sequences and series constitute a foundational topic in secondary mathematics because they support the development of pattern recognition, algebraic generalization, and mathematical problem-solving competencies frequently assessed in national examinations and applied in real-world contexts (Marzuki et al., 2024; Purnamasari et al., 2023). However, students commonly experience difficulties in distinguishing sequence types, identifying common differences, and generalizing patterns involving non-integer relationships (Hasan & Prabawanto, 2023; Wulandari & Setiawan, 2021). From the perspective of Realistic Mathematics Education (RME), such conceptual difficulties can be mitigated by situating formal mathematical ideas within contexts that are experientially meaningful and cognitively accessible to learners (Heuvel-Panhuizen & Drijvers, 2014). In contemporary educational settings, popular digital culture, particularly social media platforms embedded within adolescents' everyday experiences, offers substantial yet underexplored opportunities for informal mathematization. TikTok, characterized by its widespread popularity and algorithm-driven content engagement, closely reflects the digital practices of 21st-century learners. Preliminary survey findings revealed that 77 out of 81 students in the target classroom actively use TikTok, indicating that the platform represents a highly familiar and cognitively relevant context for mathematical exploration (De Leyn et al., 2022; Mazlan et al., 2023).

Previous studies investigating HLTs for arithmetic sequences and series have primarily employed traditional cultural contexts, such as local crafts and historical sites, or have utilised non-specific instructional settings (Andzin et al., 2024; Domu & Mangelep, 2020; Indriani et al., 2018; Lestari & Marsigit, 2020; Rawani et al., 2024). However, these studies predominantly focused on face-to-face instructional environments and non-digital classroom implementations. To date, limited research has systematically integrated a globally recognized digital platform such as TikTok into an HLT specifically designed for digital classroom ecosystems. This gap is pedagogically significant because, without instructional designs capable of bridging students' familiar digital consumption practices with structured mathematical learning trajectories, digital classrooms risk becoming technologically sophisticated yet pedagogically static.

In response to this gap, the present study develops a preliminary HLT for arithmetic sequences and series by integrating TikTok-based contexts within a collaborative digital learning environment. The proposed trajectory employs interactive platforms, such as Canva, to support students' progression from informal pattern recognition toward formal algebraic generalization through ratio tables, visual representations, and structured mathematical modelling activities. Guided by the preliminary design phase of educational design research, this study aims to develop a theoretically grounded HLT that: (1) integrates TikTok contexts as meaningful starting points for informal mathematization; (2) structures collaborative digital activities that scaffold students' transition from visual and numerical representations to formal sequence and series formulas; and (3) provides mathematics teachers with a validated instructional framework for optimizing digital classroom resources. By integrating popular culture, collaborative digital learning, and learner-centered instructional design, this research contributes a scalable model for contextualized and technology-enhanced mathematics instruction.

Methods

This study employed a design research methodology, specifically focusing on the preliminary design phase within the three-phase model proposed by Gravemeijer and Cobb (2006). The model consists of three interconnected phases: preliminary design, teaching experiment, and retrospective analysis. The present study was limited to the preliminary design phase in order to develop a theoretically grounded HLT for implementation within digital classroom environments.

The preliminary design phase emphasizes the systematic integration of theoretical perspectives, empirical classroom insights, and expert validation prior to classroom enactment. This phase is intended to ensure that the resulting instructional design is pedagogically robust, contextually relevant, and theoretically aligned with the principles of RME. Accordingly, the study focused on constructing learning activities, anticipating students' mathematical reasoning, and designing instructional pathways that support the transition from informal mathematical understanding toward formal conceptualization of arithmetic sequences and series.

Context and Participants

The proposed HLT was designed for Year 11 students participating in a digital classroom program at a senior high school in Kolaka Regency, Indonesia. The digital classroom environment was equipped with tablets, internet access, and interactive digital learning facilities intended to support collaborative and technology-enhanced instruction.

To establish the pedagogical and conceptual validity of the HLT, three experts participated in the validation process, consisting of one mathematics education lecturer and two experienced senior high school mathematics teachers. Participants were purposively selected based on their expertise in mathematics curriculum design, contextual mathematics instruction, and the integration of digital technologies in classroom learning. Their role was to critically evaluate the coherence of the instructional sequence, the contextual appropriateness of the TikTok-based activities, and the plausibility of the hypothetical student learning pathways embedded within the proposed HLT.

Data Collection Procedures

Data collection was conducted through three complementary techniques. First, a systematic literature review was undertaken to examine prior studies related to arithmetic sequences and series, HLT, RME, digital learning environments, and the integration of popular culture in mathematics instruction. This review provided the theoretical foundation for the instructional design.

Second, classroom observations were conducted in the target digital classroom to identify prevailing instructional practices, patterns of student participation, and the extent to which digital technologies were utilized during mathematics instruction. Particular attention was given to identifying discrepancies between the availability of technological infrastructure and its pedagogical implementation. Third, semi-structured interviews were conducted with mathematics teachers to explore instructional challenges, students' conceptual difficulties, contextual constraints, and opportunities for integrating TikTok-based contexts into mathematics learning. These interviews also aimed to identify teachers' perceptions regarding the feasibility of collaborative digital learning activities within the classroom setting. Finally, the findings from these three sources informed the development of the initial HLT draft, which incorporated sequenced instructional activities, anticipated student reasoning, and hypothetical learning pathways progressing from informal exploration toward formal mathematical generalization.

Data Analysis and HLT Development

The collected qualitative data were analyzed using iterative categorization and thematic synthesis techniques. Observation notes and interview transcripts were systematically coded to identify recurring themes related to instructional limitations, student misconceptions, opportunities for digital integration, and contextual relevance. Subsequently, these findings were synthesized with theoretical insights derived from the literature review to construct the initial HLT framework.

The resulting HLT consisted of two interconnected iceberg models grounded in RME principles: one focusing on arithmetic sequences and the other on arithmetic series. Each iceberg model comprised one situational context and five progressively scaffolded mathematical tasks. In addition, the trajectory incorporated hypothesized student responses, anticipated reasoning strategies, and projected cognitive transitions throughout the learning process.

The instructional design explicitly connected informal mathematical reasoning such as repeated addition, ratio tables, and visual pattern recognition to formal algebraic generalizations involving the arithmetic sequence formula (Un) and the arithmetic series formula (Sn). Collaborative activities were further integrated through digital platforms such as Canva to facilitate discussion, representation, and collective mathematical modelling within the digital classroom environment.

Validation and Quality Assurance

The content and construct validity of the proposed HLT were evaluated through a focus group discussion involving the three expert participants. The validation process examined several criteria, including mathematical accuracy, contextual relevance (i.e., TikTok popularity and alignment with the digital classroom), linguistic clarity, pedagogical coherence, instructional sequencing, and consistency with RME principles.

Each component of the HLT was reviewed using structured validation protocols, enabling experts to provide systematic feedback regarding the feasibility and theoretical coherence of the instructional design. Revisions were conducted iteratively based on expert recommendations and collective discussion until consensus was achieved among all validators.

The final validated HLT was produced only after all identified issues concerning instructional feasibility, contextual authenticity, conceptual progression, and theoretical alignment had been comprehensively addressed. Consequently, the resulting trajectory represents a pedagogically refined and theoretically grounded instructional framework for teaching arithmetic sequences and series within technology-enhanced mathematics classrooms.

Results and Discussion

The preliminary investigation confirmed that TikTok constitutes a highly accessible and culturally relevant platform for the target student population. Existing literature consistently characterizes TikTok as a dominant component of adolescents' contemporary digital culture, shaping patterns of media consumption, interaction, and engagement (De Leyn et al., 2022; Jain & Arakkal, 2022). Moreover, recent empirical studies indicate that the integration of TikTok-based media into mathematics instruction can positively influence students' engagement, participation, and academic achievement (Cuhanazriansyah et al., 2025; Magbago et al., 2025).

These findings were further supported by classroom observations and teacher interviews conducted in the target digital classroom. Most students actively engaged with TikTok content in their daily lives and demonstrated familiarity with several highly popular accounts, particularly @raimlaode94 and @jeromepolin98, both of which were recognized for their viral reach and strong cultural resonance among adolescents. Although students primarily interacted with the platform as content consumers rather than creators, their familiarity with viewer statistics, engagement patterns, and content distribution mechanisms provided a cognitively meaningful entry point for mathematical exploration.

Consequently, TikTok-based contexts were validated as pedagogically appropriate anchors for informal mathematization. This finding aligns with previous research emphasizing that authentic and experientially familiar contexts can enhance students' motivation, participation, and conceptual accessibility in mathematics learning (Ferreira & Bisognin, 2020; Vos, 2018; Yee & Bostic, 2014). Within the present study, the TikTok context was therefore positioned not merely as a motivational element, but as a meaningful contextual foundation for supporting students' transition from informal reasoning toward formal mathematical abstraction.

HLT Design I: Arithmetic Sequences Through Viewer Growth Patterns

The first instructional trajectory was designed to support students' conceptual understanding of arithmetic sequences through the interpretation of TikTok viewer-growth patterns. The trajectory was organized using an iceberg model framework (Figure 1), which guided students progressively from contextual observations toward formal algebraic representation of the arithmetic sequence formula (U_n).

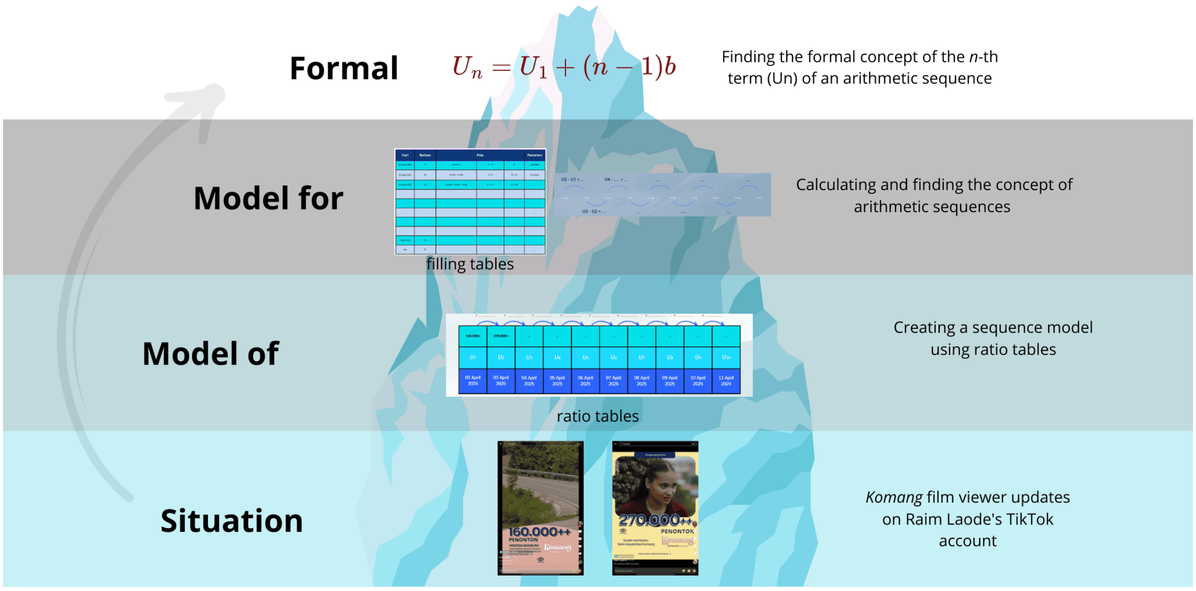

Figure 1. Iceberg Model of Arithmetic Sequences Using a Popular Context (TikTok: @raimlaode94)

The learning trajectory began with a situational problem presenting viewer statistics from the film Komang on the TikTok account @raimlaode94 during the first two days of publication, namely 160,000 and 270,000 viewers. Students were encouraged to identify the constant increase of 110,000 viewers per day, thereby establishing the initial contextual basis for recognizing arithmetic growth patterns.

Furthermore, Table 1 presents the sequential structure of the proposed HLT. Problems 1 and 2 required students to estimate the number of viewers on Days 7 and 10 through repeated addition and ratio-table strategies. These activities were intended to reinforce pattern recognition through concrete numerical manipulation and contextual reasoning.

Table 1. HLT for Arithmetic Sequences Using a Popular Context

Topic	Situation & Problem	Activities & Hypothesized Student Reasoning
Arithmetic sequence (U_n)	**Situation**: Viewer updates for *Komang* (Days 1–2) on @raimlaode94	Students observe and quantify the daily increase (110,000).
Arithmetic sequence (U_n)	**Problem 1**: Estimate viewers up to Day 7	Students apply repeated addition to project U_7.
Arithmetic sequence (U_n)	**Problem 2**: Estimate viewers up to Day 10 for director evaluation	Students use ratio tables to systematically extend the pattern to U_{10}.
Arithmetic sequence (U_n)	**Problem 3**: Verify constant daily difference	Students confirm the invariant difference between consecutive terms.
Arithmetic sequence (U_n)	**Problem 4**: Project viewers for a 30-day screening	Students generalize to $U_n = U_1 + (n - 1)\, d$ via fill-in tables.
Arithmetic sequence (U_n)	**Problem 5**: Extend screening by 15 days (total 45)	Students apply the formal formula to compute U_{45}.

In Problem 3, students were asked to verify the constancy of the common difference between consecutive terms, thereby strengthening their understanding of the defining characteristic of arithmetic sequences. Subsequently, Problem 4 introduced a structured fill-in table enabling students to observe relationships such as: $U_3 = U_1 + 2d, U_4 = U_1 + 3d$ and so on. From these observations, students gradually generalized the arithmetic sequence formula:

$$U_n = U_1 + (n - 1)d$$

Finally, Problem 5 extended the contextual scenario to a 45-day screening period, requiring students to apply the formalized formula in a more complex situation. This instructional progression intentionally delayed symbolic abstraction until students had established robust informal reasoning and contextual understanding, thereby reducing cognitive overload and promoting meaningful algebraic generalization.

HLT Design II: Arithmetic Series Through Cumulative Engagement Metrics

The second trajectory focuses on the concept of an arithmetic series (S_n) using viewer accumulation patterns from JeromePolin98. The design capitalises on the cognitive need for computational efficiency: after manually summing 12 terms, students experience the tedium of additive accumulation, which creates a didactic impetus to discover a generalised formula.

Figure 2 illustrates the progression from informal data ordering to formal series representation. Table 2 provides a breakdown of the sequential tasks. Problem 1 requires students to order nine randomly presented viewer counts and predict three additional terms to construct a coherent arithmetic sequence (1.0M–3.2M). Problem 2 involves calculating the common difference ($d = 0.2M$) using ratio columns. Problem 3 uses a folding-bar illustration (Figure 3) to show students that pairing opposite terms yields a constant sum ($U_1 + U_{12} = 4.2M$), and that exactly n/2 pairs are formed. This visual-spatial representation facilitates the derivation of $S_{12} = (U_1 + U_{12})\left(\frac{n}{2}\right)$, which equals 25.2M. Problem 4 extends the folding pattern to even values of n (2, 4, 6, 8, 10 and 12) using a fill-in table. This enables students to derive the formula $S_n = \left(\frac{n}{2}\right)(U_1 + U_n)$ inductively. Problem 5 validates the formula's applicability to odd n (15 terms), thereby reinforcing structural generalisation.

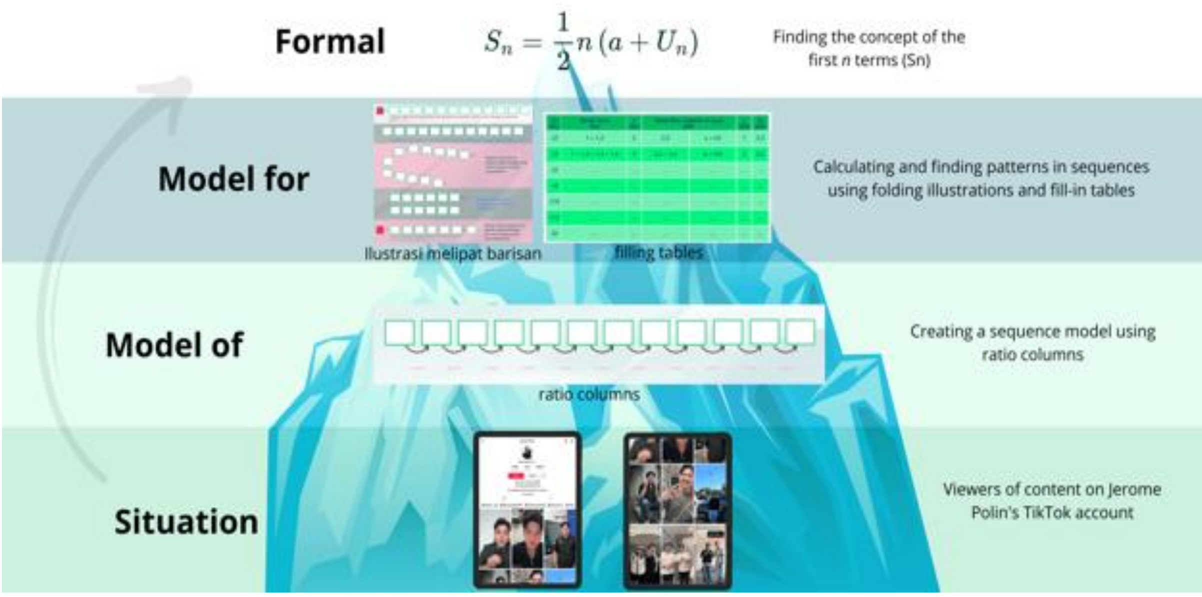

Figure 2. Arithmetic Series Iceberg Using a Popular Context (TikTok: @jeromepolin98)

The iceberg model in Figure 2 begins with a situation that presents the number of viewers displayed in nine TikTok contents by Jerome Polin, followed by a task that asks students to calculate the total number of viewers in twelve contents (S_{12}) that appear when scrolling further down. From this situation, students follow a guided didactical scenario: ordering the viewers, calculating the total, discovering an efficient way to determine the sum of viewers up to a certain sequence (concept of S_n) using the folding-bar illustration (Figure 3), and applying the formalized concept to calculate the total number of viewers across 15 contents (S_{15}).

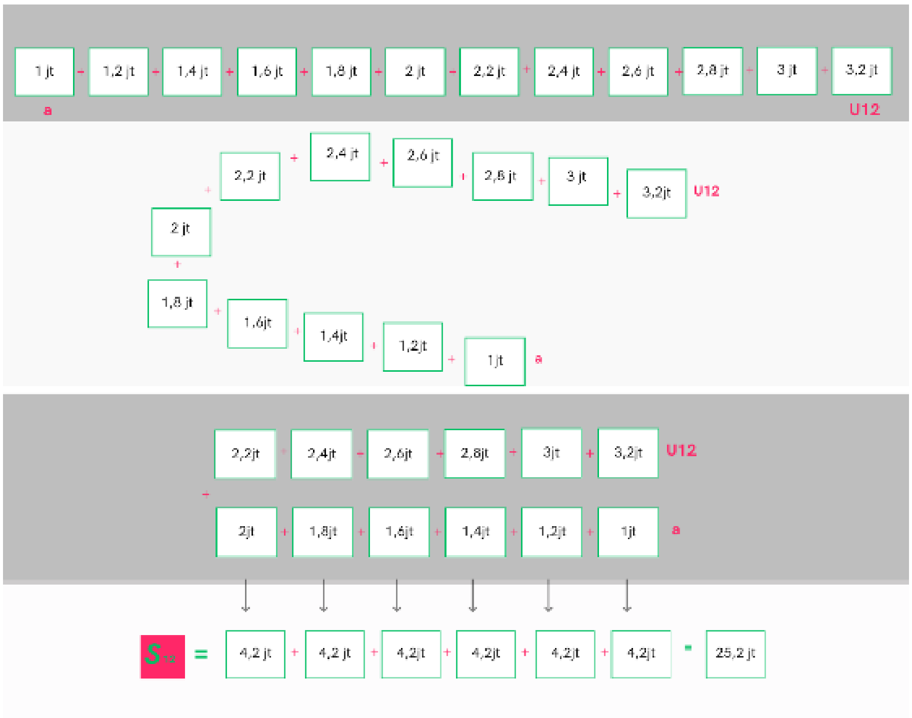

Figure 3. Arithmetic Series Folding Illustration

The learning activities and the hypotheses of students' thinking are presented in Table 2.

Table 2. HLT for Arithmetic Series Using a Popular Context

Topic	Situation & Problem	Activities & Hypothesized Student Reasoning
Arithmetic Series (S_n)	**Situation**: Viewer counts from 9 TikTok contents (@jeromepolin98)	Students observe scattered data and recognize the need for ordering.
Arithmetic Series (S_n)	**Problem 1**: Order 12 contents & predict 3 additional terms	Students construct an ascending sequence and extrapolate pattern.
Arithmetic Series (S_n)	**Problem 2**: Identify common difference	Students calculate $d = 0.2$M using ratio columns.
Arithmetic Series (S_n)	**Problem 3**: Calculate total viewers for engagement analysis	Students manually sum terms, then apply folding illustration to simplify.

Arithmetic Series (S_n)	**Problem 4**: Derive efficient method for n terms	Students generalize to $S_n = \frac{1}{2}(U_1 + U_n)$ via structured tables.
Arithmetic Series (S_n)	**Problem 5**: Recalculate total for 15 contents	Students validate formula applicability to odd n.

Theoretical Alignment and Pedagogical Mechanisms

The developed HLT operationalizes the central principle of the iceberg model, namely that formal mathematical understanding emerges from a substantial foundation of informal reasoning, contextual modelling, and pre-formal strategies (Webb, 2017). Within the present design, TikTok functions not merely as a motivational stimulus, but as a didactical instrument that situates arithmetic sequences and series within observable and quantifiable digital phenomena familiar to students.

The progression from contextual reasoning through ratio tables and visual representations toward symbolic generalization reflects the dual processes of horizontal and vertical mathematization characteristic of Realistic Mathematics Education (Heuvel-Panhuizen & Drijvers, 2014). Students initially engage in contextual problem solving grounded in familiar digital experiences before progressively formalizing these observations into algebraic representations of (U_n)) and (S_n).

In addition, the proposed HLT leverages the collaborative affordances of digital classroom environments through the integration of Canva-based interactive worksheets. Through shared digital workspaces, students can engage in simultaneous problem solving, peer discussion, collaborative modelling, and collective refinement of mathematical representations. Such collaborative interactions are consistent with Webb's (2017) argument that peer engagement and collective reasoning enhance opportunities for strategy comparison, model refinement, and conceptual negotiation. The instructional role of the teacher within this trajectory also shifts substantially from direct knowledge transmission toward facilitation of guided reinvention. Teachers provide strategic scaffolding and timely interventions while maintaining students' agency in discovering mathematical structures and relationships independently.

Compared with previous HLT studies employing traditional cultural contexts or non-digital classroom implementations (Andzin et al., 2024; Indriani et al., 2018; Rawani et al., 2024), the present study contributes two notable pedagogical innovations. First, it systematically integrates a globally recognized digital popular-culture context to activate students' informal numeracy experiences and contextual familiarity. Second, it aligns trajectory scaffolding with collaborative digital workflows, ensuring that technology functions as a medium for cognitive progression rather than merely a tool for content delivery. Finally, by embedding the core principles of RME, including reality, activity, level, interactivity, intertwinement, and guidance, within a culturally relevant digital context, the developed HLT offers a theoretically coherent and empirically grounded framework for contextualized mathematics instruction in technology-enhanced classrooms.

Conclusion

This study successfully developed a preliminary HLT for teaching arithmetic sequences and series within digital classroom environments. Drawing upon popular TikTok contexts from the accounts @raimlaode94 and @jeromepolin98, the proposed HLT consists of two structured iceberg models designed to support students' progression from informal pattern recognition toward formal algebraic generalization. Each model comprises six interconnected didactical activities, including one situational context and five progressively scaffolded mathematical tasks. The resulting instructional design was systematically validated through expert focus group discussions to ensure mathematical accuracy, contextual relevance, pedagogical coherence, and feasibility for implementation in digitally mediated learning environments.

The developed HLT operationalizes the principles of RME by transforming students' everyday digital experiences into meaningful contexts for mathematical exploration. Through the strategic use of ratio tables, structured fill-in tables, and folding illustrations, the trajectory facilitates students' transition from concrete additive reasoning toward formal derivation of the arithmetic sequence and series formulas. Furthermore, the integration of Canva as a collaborative digital platform enhances the pedagogical potential of digital classrooms by enabling simultaneous multi-device interaction, peer negotiation, and the co-construction of mathematical representations. These findings demonstrate that popular digital culture, when systematically embedded within a carefully designed instructional trajectory, can function as a productive catalyst for activating students' informal numeracy schemas and fostering formal mathematical understanding.

From a practical perspective, the proposed HLT provides mathematics educators with a validated and contextually grounded instructional framework aligned with the demands of 21st-century digital learning ecosystems. The design offers a scalable model for bridging the persistent gap between technological infrastructure and pedagogical innovation in secondary mathematics education. In particular, the study contributes an example of how digital platforms familiar to students may be transformed from passive consumption spaces into meaningful resources for mathematization and conceptual learning.

Nevertheless, several limitations should be acknowledged. Since the present study was confined to the preliminary design phase of educational design research, the effectiveness of the proposed HLT remains theoretical and has not yet been empirically tested through classroom implementation. The absence of teaching experiments and retrospective analysis limits the extent to which student learning outcomes, conceptual development, and instructional effectiveness can be validated. In addition, the study focused on a single digital classroom context, thereby restricting the generalizability of the findings to broader educational settings.

Accordingly, future research should proceed to the subsequent phases of design research by implementing and evaluating the proposed HLT in authentic classroom environments. Such investigations are necessary to examine the effectiveness of the trajectory in supporting students' conceptual understanding, refine the anticipated learning pathways, and assess students' mathematical learning gains. Further studies may also explore the adaptability of this framework across other mathematical domains, including functions, geometry, and statistics, as well as within diverse educational and technological contexts. Moreover, future investigations into the influence of teacher facilitation strategies, collaborative interaction patterns, and specific digital platform features on students' mathematical engagement would provide valuable contributions to the ongoing development of technology-enhanced mathematics education.

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Conflicts of Interest

The authors confirm that there are no conflicts of interest regarding this manuscript. All potential ethical issues, such as plagiarism, misconduct, data fabrication or falsification, duplicate submission, and redundancy, have been thoroughly considered and complied with.

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