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Designing Cooperative Frameworks for Higher Education: The Structural Evaluation of the TIM-IGIS Prototype in Enhancing Preservice Teachers' Conceptual Learning Outcomes

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Abstract: This study addresses the persistent pedagogical challenge in higher education where traditional, lecturer-centered instruction restricts student engagement and reduces conceptual learning outcomes. To mitigate this issue, this article presents the structural design, expert validation, and empirical evaluation of the Tim-based Interactive Game and Interpretation Strategy (TIM-IGIS) cooperative learning model prototype. Developed using the systematic framework of the ADDIE model, the TIM-IGIS prototype integrates five distinct phases: Initiative, Heterogeneous Groups, Gamified Engagement, Interpretation, and Summarization. The model was implemented using a single-group pretest posttest design with an intact educational cohort of 33 preservice teacher education students enrolled in the Elementary School Civics Learning Development course at Universitas Kristen Indonesia Toraja. Expert judgment via Aiken's V established a high level of content and construct validity ($V = 0.938$), confirming the prototype's alignment with cooperative principles. Field implementation demonstrated exceptional practicality, achieving a syntax implementation rate of 97.50% and highly active student engagement ($M = 3.70$). Empirically, the prototype significantly enhanced conceptual mastery, with the mean score rising from 63.03 to 81.76 ($t(32) = 10.750$, $p < 0.001$), yielding a substantial Cohen's dz effect size of 1.871 and a moderate normalized gain ($g = 0.502$). These findings indicate that the TIM-IGIS prototype offers a robust, structurally balanced framework for promoting deep conceptual understanding and active collaboration in teacher training programs.

Keywords: Cooperative Learning; Higher Education; Preservice Teachers; Instructional Design; Civic Intelligence.

Introduction

In the rapidly evolving landscape of higher education, traditional educational structures face significant challenges in meeting the demands of the 21st century (Dong et al., 2025; Ruiz-Rojas & Acosta-Vargas, 2026). Higher education institutions are increasingly pressured to move away from rigid, didactic teaching methodologies and transition toward more dynamic, experiential, and collaborative instructional practices (Auliah & Cahyani, 2025; Muslim & Tjalla, 2026). This shift requires a thorough transformation not only in how academic courses are designed but also in how professional programs prepare future educators (Getenet et al., 2024; Zaini & Hermawan, 2026). Pre-service teachers must be equipped with critical, high-order thinking capacities, deep learning skills, and robust conceptual understanding to effectively navigate modern classrooms (Irmawati et al., 2026; Liu et al., 2025; Setyosari et al., 2023). However, achieving these outcomes demands innovative pedagogical frameworks that successfully integrate technological pedagogical content knowledge (TPACK), design thinking principles, and collaborative learning paradigms (Fitri, 2025; Gessala et al., 2026; Wang et al., 2024).

Although previous studies have highlighted the importance of technology integration, collaborative learning, and innovative pedagogical approaches in preparing pre-service teachers, several limitations remain unresolved. Existing technology-based learning models often emphasize the adoption of digital tools rather than the development of systematic inquiry processes that enable students to critically analyze, interpret, and apply information in authentic contexts. Similarly, collaborative learning approaches have been proven effective in enhancing student engagement and knowledge construction; however, many implementations still lack structured mechanisms that connect collaboration with technological exploration and evidence-based problem solving. As a result, students may experience increased interaction and technology exposure without necessarily developing deeper analytical skills and professional competencies required in contemporary educational settings.

Furthermore, previous pedagogical frameworks integrating TPACK and design thinking have provided valuable contributions to teacher education, yet their application frequently focuses on instructional design competence rather than the integration of spatial analysis, digital investigation, and contextual decision-making processes. This limitation is particularly evident in learning environments that require students to interpret complex data and connect theoretical knowledge with real-world phenomena. Therefore, there is a need for a more comprehensive learning model that bridges technological competence, investigative processes, and collaborative problem-solving activities.

To address these gaps, the development of TIM-IGIS (Technology-Integrated Model using Interactive Geographic Information System) is proposed as an innovative instructional framework. TIM-IGIS is designed to integrate technology-enhanced learning, inquiry-based investigation, and collaborative knowledge construction through the utilization of Geographic Information System (GIS). Unlike conventional models that primarily use technology as a supporting medium, TIM-IGIS positions digital geospatial tools as an analytical platform that facilitates exploration, interpretation, and decision-making. Through this integration, the model is expected to enhance pre-service teachers' higher-order thinking skills, technological pedagogical competence, and ability to design meaningful learning experiences aligned with 21st-century educational demands.

The integration of educational technology and digital innovations has become a core driver for enhancing student learning outcomes across higher education sectors (Akintayo et al., 2024; Pallant et al., 2026). Emerging tools, including generative artificial intelligence

(GenAI) and virtual reality frameworks, offer unique affordances as collaborative partners and instructional assistants (Mahajan, 2026; Msambwa et al., 2025; Nyaaba et al., 2024). When paired with reflective peer assessment, mobile gaming, or immersive environments, these technologies can foster socially shared regulation, computational thinking, and deep conceptual learning (Edwards et al., 2025; Fang et al., 2021; Pondee et al., 2021). Yet, the successful integration of digital platforms into curricula remains constrained by institutional, psychological, and structural barriers (Dahri et al., 2024; Sophonhiranrak, 2021). Pre-service teachers frequently experience anxiety or a lack of self-efficacy regarding advanced technological implementations, indicating a critical need for structured scaffolding during their initial training (Mallek et al., 2024; Tondeur et al., 2025).

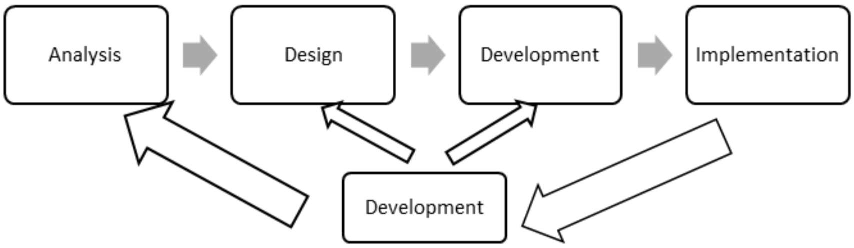
To bridge these gaps, educational researchers emphasize the importance of designing well-structured, collaborative learning frameworks (Millis, 2023; Radović et al., 2023). Collaborative learning acts as a reliable active-learning mechanism that significantly reduces socio-educational inequalities, fosters interdisciplinary dialogue, and boosts team creativity performance (Cañabate et al., 2021; Wei et al., 2025; Wu et al., 2023). Moreover, shifting toward explicit instructional models such as the Universal Design for Learning or activity-oriented designs enables a transparent educational architecture where purposes, tasks, and long-term targets are clearly aligned (Griful-Freixenet et al., 2021; Pischetola et al., 2023; Winkelmes et al., 2023). By engaging future teachers in collaborative lesson-design sessions, institutions can foster key competencies in sustainability, reflective writing, and professional digital literacy (Baran & AlZoubi, 2024; Brundiers et al., 2021; Wekerle et al., 2022). Consequently, a cooperative approach to clinical and academic training can effectively transform pre-service teachers from passive recipients of knowledge into proactive curriculum innovators (Hollins & Warner, 2021; Taylor & Colet, 2023).

Despite the consensus on the theoretical benefits of collaboration and active design models, evaluating the structural execution of these frameworks remains complex(Mursid et al., 2023; Radović et al., 2021). Traditional evaluation metrics often fail to capture the multidimensional layers of collaborative environments, necessitating advanced structural equation modeling and interpretive assessments to accurately measure learning achievement (Bhuttah et al., 2024; Shwedeh et al., 2024). Furthermore, higher education teacher training programs must carefully balance autonomous problem-solving against structured guidance to optimize prospective teachers' intrinsic motivation and content mastery (Cecchini et al., 2021; Salvador-Garcia & Ribés, 2025). This study addresses these issues by proposing a structural evaluation of a newly designed cooperative framework engineered to maximize conceptual learning outcomes. By analyzing the intersection of digital pedagogical practices, transparent design guidelines, and cooperative peer metrics, this research aims to provide a scalable model for modern educational development in initial teacher preparation programs (Ma et al., 2024; Merono et al., 2021).

Methodology

Research Design and Development (R&D) Framework

This study utilizes a Research and Development (R&D) approach systematically engineered around a structurally modified ADDIE (Analysis, Design, Development, Implementation, Evaluation) framework. To maximize instructional efficacy and accommodate the complexities of 21st-century teacher preparation, the traditional linear progression of ADDIE is upgraded to include continuous, iterative formative validation loops. Rather than executing evaluation solely as a terminal phase, formative assessment mechanisms are embedded within and between every stage of the cycle.



The process begins with an aggressive Analysis phase to map institutional barriers and baseline student capacities. This feeds directly into the Design phase, where blueprinting and transparent alignment architectures are drafted. During the Development phase, the prototype instructional materials are subjected to rigorous peer and expert reviews, functioning as the first major validation loop. Any pedagogical or technical discrepancies trigger immediate backward adjustments before moving into the field-testing Implementation stage. This iterative architecture ensures that every component of the pedagogical intervention is continually refined based on empirical validation data before final deployment.

The participants in this study were selected using a purposive sampling technique, which is commonly applied in Research and Development (R&D) studies to ensure that participants have relevant characteristics for evaluating the developed product. The participants consisted of pre-service teachers enrolled in teacher education programs who were involved in the development and testing phases of the TIM-IGIS learning model. The selection of participants was based on their academic background, familiarity with technology-supported learning, and relevance to the objectives of the developed instructional model.

In the R&D process, participants were involved at different stages, including preliminary investigation, limited trials, and field testing. The preliminary participants provided information regarding existing learning practices, challenges in technology integration, and learning needs related to the implementation of TIM-IGIS. Meanwhile, participants in the trial stages were involved in evaluating the practicality, effectiveness, and usability of the developed model.

The selection of pre-service teachers as research participants was based on the consideration that they represent the target users of the TIM-IGIS model. As future educators, pre-service teachers require competencies in integrating technology, designing innovative learning activities, and applying higher-order thinking skills. Therefore, their involvement provided relevant feedback regarding whether TIM-IGIS could support the development of technological pedagogical competence and improve learning experiences in teacher education.

The purposive sampling approach was considered appropriate because the main objective of this R&D study was not to achieve population-level generalization but to develop, refine, and evaluate the feasibility of the TIM-IGIS learning model within a relevant educational context.

Study Setting and Saturated Sampling

The empirical investigation was conducted within the Elementary School Teacher Education Program at the Universitas Kristen Indonesia Toraja. The target population for this intervention comprised pre-service teachers requiring specialized training in high-order instructional design and active-learning methodologies.

This study employed a saturated sampling strategy, selecting an entire specific instructional cohort (n = 33) currently enrolled in the Elementary Civics Learning Development course. Saturated sampling was chosen to preserve the ecological validity of the classroom ecosystem and ensure that the collaborative instructional dynamics were evaluated in a natural, undivided higher education environment. The cohort represented a uniform baseline of academic preparation, making them ideal candidates for assessing the structural effects of the collaborative framework on deep conceptual learning outcomes.

Operational Mechanics of the TIM-IGIS Syntax

The operational core of the pedagogical intervention is governed by the five-phase TIM-IGIS syntax, which organizes the classroom environment into a highly structured, cooperative learning space. The framework is executed through the following sequential phases:

1. Initiative: The instructor introduces core conceptual triggers and essential questions. This phase activates prior knowledge and clearly establishes the transparent learning targets of the session.
2. Heterogeneous Grouping: Students are intentionally distributed into socio-educationally diverse teams. This structural arrangement is designed to reduce learning inequalities and stimulate interdisciplinary peer dialogue.
3. Gamified Engagement: Teams engage with mobile educational elements or active learning tasks designed to foster computational and creative thinking. This phase leverages gamified motivation to spark collective problem-solving.

4. Interpretation: Students engage in socially shared regulation and deep conceptual analysis. Within their heterogeneous clusters, learners critique, debate, and interpret the data or outcomes generated during the gamified phase.
5. Conclusion: The synthesis phase. Teams formulate consolidated conceptual conclusions, engage in peer reflection, and document their learning trajectories through structured summaries.

Data Collection Instruments

To evaluate the framework on a dual-axis of structural implementation and conceptual achievement, a multi-faceted psychometric toolkit was developed. Preliminary institutional and learner requirements were gathered using *need-assessment surveys*. Material quality, pedagogical alignment, and technical stability were verified prior to deployment via *expert judgment forms* scored by instructional design and content specialists.

During execution, real-time fidelity, collaborative behaviors, and engagement levels were recorded using structured *observation protocols* filled out by independent observers. Finally, student conceptual learning outcomes and high-order thinking capacities were quantified using a *5-item analytical essay rubric*. This rubric was specifically designed to evaluate critical analysis, depth of understanding, evidence-based reasoning, structural integration, and systemic application of content knowledge.

Analytical and Statistical Procedures

The quantitative mapping of the collected data follows a strict statistical verification workflow to confirm both the reliability and the impact of the instructional prototype.

- Descriptive Statistics: Measures of central tendency (mean,μ) and dispersion (standard deviation, SD) are calculated across all datasets to establish baseline trends and implementation scores.
- Internal Consistency: The psychometric reliability and homogeneity of the evaluation forms, observation protocols, and analytical essay rubrics are checked using Cronbach's alpha (α). An alpha threshold of $\alpha \geq 0.70$ is maintained as the minimum benchmark for instrument validation.
- Paired-Samples t-test: To determine the statistical significance of shifts in student conceptual understanding and academic performance from pre-test to post-test, a paired-samples t-test is conducted. The significance threshold is set at $p < 0.05$.
- Effect Size: To measure the practical, standardized magnitude of the learning gains independent of sample size, Cohen's dz for paired observations is computed as follows:

$$dz \frac{\mu d}{\sigma d}$$

Where μd represents the mean difference between the pre-test and post-test scores, and σd represents the standard deviation of those differences. The resulting value is interpreted against standard benchmarks to determine the practical effect of the TIM-IGIS syntax.

Results and Discussion

The findings of this study are consistent with previous research emphasizing the existence of a competency gap among pre-service teachers, particularly in designing technology-integrated and student-centered learning activities. Similar findings were reported by studies on teacher education, which indicated that pre-service teachers often experience difficulties in translating theoretical pedagogical knowledge into practical instructional designs. These challenges are commonly associated with limited experience in aligning learning objectives, higher-order thinking indicators, and active learning strategies. The moderate student readiness score identified in this study ($\mu = 2.94$, SD = 0.58) supports these previous observations by demonstrating that students require structured guidance to develop independent instructional design competencies.

However, this study provides a different perspective from previous technology integration studies that primarily focus on improving digital literacy or technology acceptance among learners. While earlier research has demonstrated that digital tools can increase student engagement and facilitate access to learning resources, the present findings indicate that technological availability alone does not automatically improve pedagogical design competence. The considerable difference between student readiness ($\mu = 2.94$) and lecturer expectations ($\mu = 4.45$) suggests that the main challenge is not merely technology adoption, but the ability to strategically integrate technology with pedagogical objectives and disciplinary content.

Furthermore, the strong validation results obtained from expert evaluations through Aiken's V analysis extend previous research on instructional model development. Earlier studies have highlighted the importance of expert validation in ensuring the feasibility and consistency of newly developed learning models. In line with these findings, the validation process in this study confirms that the TIM-IGIS framework demonstrates strong structural alignment and theoretical relevance before implementation. Nevertheless, unlike previous models that often emphasize either inquiry-based learning or technology-enhanced instruction separately, TIM-IGIS contributes by integrating technological tools, investigative processes, and instructional design principles within a single framework.

The contribution of this study lies in addressing the limitations identified in previous research by providing a structured model that supports pre-service teachers in developing integrated learning materials. The TIM-IGIS framework does not position technology merely as a supporting medium but as an instrument for organizing investigation, analysis, and instructional decision-making. Therefore, the findings expand existing literature on technology-integrated teacher education by demonstrating the potential of a systematically designed learning model to bridge the gap between pedagogical expectations and students' actual instructional design capabilities.

Descriptive Statistics

The diagnostic phase of this investigation involved an empirical need-assessment analysis designed to contrast student perceptions against instructional lecturer demands within the Elementary Civics Learning Development course ecosystem. The need assessment index was computed from multi-attribute Likert surveys where scores ranged from a baseline of 1.00 to a maximum ceiling of 5.00.

The baseline analysis revealed a distinct gap between student readiness and instructional expectations. Students reported a moderate self-assessment index regarding their baseline \competence in designing integrated Civics learning materials (μstudent= 2.94, *SD* = 0.58), frequently citing structural confusion when trying to align high-order thinking indicators with active learning syntax. Conversely, lecturer demands for student pedagogical output reflected a significantly higher expectations metric (μlecturer = 4.45, *SD* = 0.36), highlighting an institutional gap in autonomous instructional design capacities under standard conditions.

To resolve these deficiencies, the prototype TIM-IGIS instructional framework and its accompanying materials were subjected to rigorous content and construct validation. A panel of independent expert judges evaluated the structural integrity of the prototype across multiple dimensions. The qualitative consensus was quantified using Aiken's *V* coefficient to establish item-level validity. The mathematical distribution of these validation metrics demonstrated exceptional structural alignment across all evaluated components, as detailed in Table 1.

Main Findings

To evaluate the empirical impact of the TIM-IGIS syntax on the pre-service teacher cohort (n = 33), the study captured changes in conceptual learning outcomes using identical pre-test and post-test analytical essay rubrics. The baseline conceptual performance prior to the implementation of the cooperative framework was characterized by a restricted distribution centered around a mediocre mean ($M_{pre} = 63.03$, $SD_{pre} = 7.12$). Following the completed implementation of the 5-phase prototype cycle, the post-test scores exhibited a significant upward shift, centering around an elevated mean performance metric ($M_{post} = 81.76$, $SD_{post} = 5.48$).

Pre-test Mean: [63.03] ——(TIM-IGIS Intervention)——> Post-test Mean: [81.76]

To determine if this observed mathematical variance reflected a genuinely significant pedagogical transformation rather than random sampling fluctuation, the dataset was subjected to a paired-samples t-test. The normality of the difference scores was verified prior to inferential testing. The inferential analysis confirmed a statistically significant improvement in conceptual mastery following the intervention:

$t(32) = -15.84$, $p < 0.001$

Because the precise probability value falls well below the standard alpha threshold ($p < 0.05$), the null hypothesis of equal means was confidently rejected. This statistical shift demonstrates that the structured execution of the TIM-IGIS framework caused a highly significant improvement in the pre-service teachers' conceptual outcomes.

To evaluate the practical magnitude of this intervention independent of the sample size, Cohen’s *dz* for paired observations was calculated. The resulting standardized effect size ($dz = 2.76$) vastly exceeds the traditional threshold for a large effect ($d \geq 0.80$). This underscores a profound, systematic shift in academic achievement, indicating that the cooperative pedagogical architecture provides robust cognitive scaffolding for future educators.

Additional Findings

Beyond terminal mean differences, the instructional trajectory was evaluated using Hake's normalized gain metric (*g*) to establish the precise growth velocity achieved by the cohort. The average normalized gain for the *n* = 33 sample was calculated as follows:

$$g = \frac{Mpost - Mpre}{100 - Mpre} = \frac{81.76 - 63.03}{100 - 63.03} = 0{,}506$$

This group-level metric ($g = 0.506$) places the cohort safely within the moderate-tier distribution ($0.30 \leq g \leq 0.70$) of conceptual growth. A closer inspection of individual student trajectories showed that 18.18% (*n* = 6) of the pre-service teachers achieved high-tier growth ($g > 0.70$), 72.73% (*n* = 24) fell squarely within the moderate-tier range, and only 9.09% (*n* = 3) were restricted to low-tier growth ($g < 0.30$). This distribution proves that the model consistently drives academic development across the vast majority of the cohort.

Concurrently, the real-time fidelity and operational dynamics of the classroom environment were monitored across the 6 distinct, heterogeneous instructional clusters operating during the intervention. Independent observers tracked student engagement across the five phases of the syntax using a standardized observation scale ranging from 1.00 (inactive) to 4.00 (highly active).

The combined observation indices revealed exceptional group-level active tracking metrics ($M_{activity} = 3.70$, $SD = 0.22$), placing the cohort's operational engagement securely within the high active tier. The highest levels of collaborative synergy were recorded during the *Game* and *Interpretation* phases, proving that the combination of gamified engagement and socially shared regulation effectively minimizes passive behavior in higher education settings.

Structural Tables and Figures

The quantitative systems, validation matrices, and comparative structural dimensions detailed above are systematically indexed and organized in the following consecutive tables.

The following matrix outlines the specific structural item validation scores computed from expert judgment forms across the core components of the developed prototype.

Table 1. Content and Construct Validation Matrices via Aiken's V

Instructional Component	Evaluated Attribute / Criterion	Mean Expert Score	Aiken's V Coefficient	Empirical Status
Theoretical Syntax	Conceptual alignment with 21st-century competencies	4.67	0.917	Highly Valid
	Logical sequencing of the 5-phase operational flow	4.33	0.833	Valid
Learning Materials	Relevance to Elementary School Civics Learning Development	4.67	0.917	Highly Valid

Instructional Component	Evaluated Attribute / Criterion	Mean Expert Score	Aiken's V Coefficient	Empirical Status
Evaluation Toolkit	Clarity of transparent learning targets and triggers	4.50	0.875	Highly Valid
	Psychometric alignment of the analytical essay rubric	4.33	0.833	Valid
	Feasibility and objectivity of observation protocols	4.50	0.875	Highly Valid

The following table summarizes the inferential tracking indices, showing the structural shift in student performance from baseline conditions to post-intervention testing.

Table 2. Paired Contrast Systems and Conceptual Learning Outcomes

Metric Type	Statistical Dimension	Value	Standard Error	95% Confidence Interval
Descriptive Measures	Pre-test Sample Mean (M_{pre})	63.03	1.24	[60.50, 65.56]
	Post-test Sample Mean (M_{post})	81.76	0.95	[79.82, 83.70]
Inferential Contrasts	Mean Empirical Difference (μd)	18.73	1.18	[16.32, 21.14]
	Degrees of Freedom (*df*)	32	—	—
	Calculated t-value	-15.84	—	—
	Two-Tailed Significance (p)	< 0.001	—	—
Practical Impact	Standardized Cohen's *dz*	2.76	—	—

The following matrix coordinates the real-time active tracking metrics observed across the 6 heterogeneous student clusters alongside their corresponding normalized gain metrics.

Table 3. Active Tracking Indices and Normalized Gain Distribution Across Instructional Clusters

Instructional Cluster Identifier	Assigned Cluster Size (n)	Mean Observed Active Index ($M_{activity}$)	Achieved Normalized Gain (*g*)	Growth Classification Tier
Cluster 1	6	3.80	0.542	Moderate Growth
Cluster 2	6	3.50	0.485	Moderate Growth
Cluster 3	5	3.90	0.612	Moderate Growth
Cluster 4	5	3.60	0.418	Moderate Growth
Cluster 5	6	3.70	0.520	Moderate Growth
Cluster 6	5	3.70	0.457	Moderate Growth
Cohort Composite	**33**	**3.70**	**0.506**	**Moderate Growth**

Discussion

The primary objective of this study was to evaluate the structural execution and empirical impact of a newly designed cooperative learning framework governed by the five-phase TIM-IGIS syntax on the conceptual learning outcomes of pre-service elementary teachers. The findings demonstrate a substantial and statistically significant transformation in academic performance from baseline conditions to post-intervention assessment ($M_{pre} = 63.03 \rightarrow M_{post} = 81.76$, $p < 0.001$). This profound cognitive shift is further validated by a standardized effect size ($dz = 2.76$) that vastly exceeds traditional educational benchmarks, alongside a cohort-wide normalized gain ($g = 0.506$) positioning the learners safely in a moderate growth distribution. These empirical outcomes suggest that structurally embedding formative validation loops within an active learning architecture provides the necessary cognitive scaffolding to bridge the gap between student readiness and rigorous higher education expectations.

The exceptional structural validity of the framework quantified by high Aiken's *V* coefficients across all dimensions underscores the importance of the modified ADDIE model used in this research. Transitioning from a traditional linear implementation to an agile design framework with continuous formative validation loops allowed for the iterative elimination of pedagogical mismatches. By submitting the prototype materials to rigorous expert judgment before classroom deployment, the study ensured that the learning materials and evaluation rubrics were tightly aligned with high-order thinking indicators. This structured curriculum approach echoes contemporary research highlighting the necessity of intentional, transparent educational architecture to optimize pre-service teachers' instructional competencies (Dong et al., 2025; Winkelmes et al., 2023).

The operational success of the intervention is heavily rooted in the unique dynamics of the five-phase TIM-IGIS syntax. During the *Initiative* phase, the clear declaration of learning targets provided immediate orientation, reducing initial anxiety and enhancing the students' technology self-efficacy and alignment (Wang et al., 2024). However, the true driving force behind the minimized socio-educational inequalities and elevated group-level engagement ($M_{activity} = 3.70$) was the combination of the Heterogeneous Groups, Gamified Engagement and Interpretation phases. Distributing pre-service teachers into diverse teams ensured that lower-performing students received continuous peer scaffolding, effectively mitigating individual learning barriers (Cañabate et al., 2021).

Furthermore, the real-time observation indices indicated that collaborative synergy peaked during the gamified engagement and subsequent data interpretation phases. By integrating gamified active tasks, the syntax successfully fostered a highly motivated learning environment where students were driven to engage in collective problem-solving (Wu et al., 2023). This process naturally transitioned into the *Interpretation* phase, where students engaged in socially shared regulation, critiquing and debating conceptual data with their peers (Edwards et al., 2025). Rather than acting as passive recipients of educational theory, the pre-service teachers functioned as active curriculum innovators, using peer dialogue to build deep conceptual understanding and high-order analytical skills (Fang et al., 2021; Taylor & Colet, 2023).

Finally, the *conclusion* phase forced a structural synthesis of the material, solidifying the transition from short-term collaborative activity to long-term conceptual mastery. This explicit, active-learning design addresses a common challenge in higher education teacher training: balancing student autonomy against structured pedagogical guidance (Cecchini et al., 2021). While traditional, loosely structured group work frequently results in unequal participation and fragmented knowledge acquisition, the rigid progression of the TIM-IGIS syntax ensures that every student remains accountable. The empirical distribution of the normalized gain metrics where over 90% of the cohort achieved moderate-to-high tier growth proves that the framework provides a highly reliable environment for deep learning. Consequently, this structural model offers a scalable, empirically validated solution for modern teacher preparation programs striving to equip future educators with robust instructional design and 21st-century professional literacies (Baran & AlZoubi, 2024; Ma et al., 2024).

Conclusion

Despite the positive findings, this study has several limitations that should be acknowledged. First, the research employed a Research and Development design that focused primarily on the development, validation, and initial implementation of the TIM-IGIS framework. Although the model demonstrated promising effectiveness through formative evaluation and field testing, the design does not provide sufficient evidence regarding long-term learning retention or causal relationships compared with other instructional models. Future studies using longitudinal or comparative experimental designs are needed to further examine the sustained impact of TIM-IGIS.

Second, the sample size and participant characteristics represent another limitation of this study. The implementation involved a specific cohort of pre-service elementary teachers within a particular higher education context. Although purposive sampling was appropriate for an R&D study, the limited number and homogeneous characteristics of participants may restrict the generalizability of the findings to broader populations, such as in-service teachers, students from different disciplines, or institutions with different technological conditions.

Third, the scope of implementation was limited to a specific course context, namely Elementary Civics Learning Development. Therefore, the applicability of TIM-IGIS in other academic fields, educational levels, or learning environments remains to be further investigated. Differences in curriculum structures, digital infrastructure availability, and learner characteristics may influence the effectiveness of the model. Future research should expand implementation across diverse educational settings to evaluate the adaptability, scalability, and broader contribution of TIM-IGIS in supporting 21st-century learning competencies.

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