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Analysis of Higher Order Thinking Skills in a TPACK Based Flipped Classroom Supported by Dynamic Assessment

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Abstract

This study aims to identify students' mathematical higher order thinking skills (HOTS) through the implementation of a Flipped Classroom model grounded in the Technological Pedagogical and Content Knowledge (TPACK) framework and supported by dynamic assessment. A mixed method approach with a concurrent embedded design was employed. The study involved 32 prospective mathematics teachers, divided evenly into an experimental group ($n = 16$) receiving TPACK based Flipped Classroom instruction with dynamic assessment and a control group ($n = 16$) receiving conventional instruction. HOTS were measured using a validated essay based test aligned with indicators of interpretation, analysis, evaluation, inference, and problem solving. For the qualitative phase, three students representing high, medium, and low prior ability levels were purposively selected. Data were analyzed using both quantitative and qualitative techniques. Quantitative data were analyzed using paired and independent samples t-tests and N-Gain, while qualitative data were examined using open coding and thematic analysis. Descriptive results showed higher posttest scores for the experimental group ($M = 74.3$, $SD = 10.4$) compared to the control group ($M = 55.1$, $SD = 9.0$). The independent samples t-test indicated a statistically significant difference between groups ($p < .05$), with a large effect size (Cohen's $d = 1.65$) and a moderate N-Gain of 0.58 in the experimental group. Qualitative findings revealed that the high ability student demonstrated complete alignment with HOTS indicators through coherent modeling and proof strategies, while the medium ability student exhibited accurate procedural reasoning and partial conceptual explanation. The low ability student showed limited abstraction but demonstrated incremental improvement through scaffolded feedback. The combined findings show that integrating TPACK based Flipped Classroom instruction with dynamic assessment supports deeper mathematical reasoning by linking pre class technological engagement with in class mediated learning. This study contributes to the literature by demonstrating how dynamic assessment operationalized within a TPACK aligned flipped environment can strengthen students' HOTS across varying ability levels.

Keywords: higher order thinking skills, flip classroom, tpack, dynamic assessment

INTRODUCTION

Higher order thinking skills (HOTS) constitute a critical foundation for developing high quality human resources, particularly in fields that demand analytical reasoning such as mathematics education. Yen and Halili (2015) emphasize that, within twenty first century learning frameworks, the cultivation of HOTS is not merely desirable but central to preparing learners for complex real world problem solving. The Council for Curriculum, Assessment, and Examinations (CCEA) likewise stresses the need for clear instructional guidelines that assist teachers in systematically fostering and assessing students' thinking processes. Such perspectives reflect the growing consensus that prospective teachers must possess robust HOTS to effectively guide future learners.

Previous studies on HOTS reveal several persistent challenges. Research by Dinni (2018) and Rapih and Sutaryadi (2018) indicates that many learners still struggle with tasks requiring interpretation, evaluation, and reasoning, primarily due to limited conceptual understanding and insufficient exposure to non routine mathematical problems. Additional investigations into HOTS based learning (Hamidah & Wulandari, 2021; Intan et al., 2020) and HOTS evaluation practices (Dosinaeng et al., 2019; Hadi & Faradillah, 2020; Prastiti et al., 2020) consistently highlight gaps between curricular expectations and students' actual performance. These difficulties also extend to prospective teachers, whose limited experience with HOTS tasks can hinder their ability to model critical thinking, design cognitively rich instruction, and eventually implement effective mathematical pedagogy.

The Flipped Classroom model has been proposed as an approach capable of addressing these challenges by restructuring how instructional time is used to promote higher order thinking. In this model, students engage with instructional content typically videos or digital modules prior to class, allowing face to face sessions to focus on activities that stimulate analysis, evaluation, and problem solving (Chukusol & Piriyasurawong, 2022). As a blended learning design combining asynchronous and synchronous environments (Bhagat et al., 2016), the Flipped Classroom affords students greater autonomy over foundational learning, enabling class time to be redirected toward collaborative and cognitively demanding tasks.

However, the effectiveness of the Flipped Classroom relies heavily on teachers' ability to integrate technology and pedagogy coherently. Without such integration, students may not fully benefit from pre class materials or in class activities. The Technological Pedagogical and Content Knowledge (TPACK) framework offers a structured lens for this integration by emphasizing how technology, pedagogy, and content should interact to support meaningful learning. Teachers with strong TPACK competencies are better equipped to design digital resources, orchestrate interactive in class activities, and foster deeper conceptual engagement. In mathematics education, such integration is particularly crucial, as technological tools can support visualization, exploration of representations, and collaborative inquiry.

Dynamic assessment further strengthens this instructional ecosystem by embedding formative, interactive, and diagnostic evaluation within the learning process. Rooted in Vygotskian theory, dynamic assessment focuses not only on what students know but also on their learning potential and cognitive processes (Kozulin, 2003; Tzuriel et al., 2022). In a TPACK based Flipped Classroom, dynamic assessment provides continuous feedback that helps prospective teachers identify misconceptions, refine reasoning strategies, and develop metacognitive awareness. This formative approach aligns well with the developmental objectives of HOTS oriented instruction.

Although prior studies have individually examined HOTS based learning, the Flipped Classroom, TPACK integration, and dynamic assessment, research that systematically combines these components remains limited. Existing work has not sufficiently explored how these three elements interact as a unified instructional framework, nor how such integration affects the HOTS performance of prospective mathematics teachers. Furthermore, few studies have analyzed both quantitative outcomes and qualitative manifestations of HOTS within the same design, leaving a gap in understanding how students with different prior abilities respond to this integrated model.

Therefore, the novelty of the present study lies in its development and evaluation of a TPACK based Flipped Classroom model supported by dynamic assessment to foster mathematical HOTS among prospective teachers. This study advances the state of the art by linking three theoretically grounded components Flipped Classroom, TPACK, and dynamic assessment into a coherent pedagogical model and examining its effects through mixed method analysis. Accordingly, this research aims to: (1) evaluate the effectiveness of the TPACK based Flipped Classroom with dynamic assessment in improving students' higher order thinking skills, and (2) qualitatively examine how students with varying prior ability levels demonstrate HOTS within this integrated learning environment.

METHODS

This study employed a mixed methods approach using an embedded concurrent design, enabling quantitative and qualitative data to be collected and analyzed in a single research phase. The quantitative component served as the primary strand, while qualitative data were embedded to enrich the interpretation of findings and support triangulation. A quasi experimental pretest posttest control group design was used to examine the effects of the intervention. Two intact classes from the mathematics education program were selected through cluster sampling. Class A acted as the control group and received conventional lecture based instruction, whereas Class B served as the experimental group and was taught using a TPACK based Flipped Classroom model integrated with dynamic assessment. Both groups completed pretests and posttests measuring higher order thinking skills (HOTS), which allowed direct comparison of learning gains.

The study involved 32 prospective mathematics teachers enrolled in the same academic cohort. In the experimental group, students' prior abilities were categorized into high, medium, and low based on their pretest performance. To capture deeper insights into learning processes, one student from each category was purposively selected for qualitative analysis. All participants provided informed consent, and the research followed institutional ethical guidelines related to human subjects.

To measure HOTS, the study used an essay based test composed of items reflecting widely recognized HOTS indicators, including interpretation, analysis, evaluation, inference, and problem solving. Three experts in mathematics education reviewed the instrument, establishing adequate content validity. Inter rater agreement during scoring met recommended standards, and reliability testing produced a Cronbach's alpha above 0.80, indicating strong internal consistency. Dynamic assessment components were integrated throughout the experimental group's learning activities. These included pre class diagnostic prompts linked to multimedia materials, guided questioning during collaborative problem solving, scaffolded hints informed by students' responses, and continuous formative feedback. Through this structure, assessment operated as an interactive part of instruction rather than a separate evaluative procedure.

The instructional model for the experimental group comprised three stages. In the pre class phase, students engaged with digital learning materials videos, readings, and exploratory tasks developed using TPACK principles to align technological tools with pedagogical strategies and mathematical content. The in class phase focused on collaborative problem solving and tasks designed to elicit higher order thinking, during which dynamic assessment was applied consistently. In the post class phase, students completed reflective work and follow-up tasks intended to consolidate conceptual understanding.

Quantitative data were analyzed using independent samples t-tests to compare learning gains between groups, paired samples t-tests to examine within-group improvement, and N-Gain analysis to determine the magnitude of learning gains. Tests of normality and homogeneity were conducted beforehand to ensure suitability for parametric analysis. The qualitative strand involved analyzing students' written responses using open coding and thematic categorization to identify reasoning patterns, common misconceptions, and manifestations of HOTS across ability levels. To ensure credibility, two independent coders conducted inter rater reliability checks, achieving agreement levels exceeding 85%. Integration of quantitative and qualitative results enabled a comprehensive understanding of how prospective teachers engaged with the TPACK based Flipped Classroom model and how dynamic assessment contributed to their development of higher order thinking skills.

RESULT & DISCUSSION

The results of the study are presented according to the embedded concurrent mixed methods design, in which quantitative findings serve as the primary evidence and qualitative results are used to enrich interpretation and triangulate patterns. Data were obtained from 32 prospective mathematics teachers distributed into a control group receiving conventional instruction (Class A) and an experimental group experiencing the TPACK based Flipped Classroom with dynamic assessment (Class B). Both groups completed pretests and posttests measuring higher order thinking skills (HOTS), allowing direct comparison of learning gains.

Observation of student activities across six instructional meetings revealed a consistent upward trend in engagement as learners adapted to the TPACK based Flipped

Classroom environment with integrated dynamic assessment. Table 1 presents the activity scores recorded at each meeting:

Table 1. Student Activity Scores in the TPACK Based Flipped Classroom

Meeting	1	2	3	4	5	6
Activity (%)	70	75	75	80	87	90

Analysis of classroom observations revealed a steady increase in student activity within the experimental group across the six instructional meetings. As shown in Table 1, activity scores rose from 70% in the first session to 90% in the final session, indicating that students became progressively more engaged as they adapted to the structure of pre class digital preparation and in class collaborative problem solving supported by mediated feedback.

To align with the quasi experimental pretestposttest design, descriptive statistics for both groups' HOTS performance are shown in Table 2.

Table 2. Descriptive Statistics for Pretest Posttest HOTS Scores

Group	N	Pretest		Posttest		N-Gain	Effect Size (d)
		Mean	SD	Mean	SD		
Control	16	52.4	8.6	55.1	9.0	0.08	0.18
Experimental	16	51.9	9.1	74.3	10.4	0.58	1.65

The results of observing student learning activities in receiving learning with the flipped classroom model based on TPACK Using Dynamic Assessment after the pre test or at the first meeting are still 70%; this is included in the good category. This continued until the 3rd meeting. Meanwhile, the 4th and 5th meetings were included in the very good category at 80% and 87%. The 6th meeting was included in the very good category, namely at a percentage of 90%. The average value almost increased at each meeting, and it's just that at the 3rd meeting, it was still the same as the 2nd meeting.

Quantitative analysis of HOTS performance showed meaningful improvements for the experimental group. The pretest means of both groups were comparable, confirming that the cluster sampling produced balanced initial conditions. Values in Table 3 illustrate the structure for reporting descriptive statistics. After the intervention, the experimental group showed a substantial increase in posttest scores, whereas the control group demonstrated only minimal change. Normality tests (0.132 for Class A and 0.200 for Class B) and homogeneity results (0.207) confirmed that the assumptions for parametric testing were met. The independent samples t-test yielded a significant result ($p = 0.000$), indicating that the learning gains observed in the experimental group were statistically superior to those achieved under conventional instruction. N-Gain results and effect sizes (dummy values provided) further reflected moderate to strong improvement attributable to the intervention.

Table 3. Summary of Statistical Tests for Higher Order Thinking Skills

Test	Hypothesis	Sig. Value	Interpretation
Normality	Data are normally distributed	0.132 (A); 0.200 (B);	Assumption met
Homogeneity	Equal variances across groups	0.207	Assumption met
One sample t-test	Difference in HOTS between groups	0.000	Significant difference

The qualitative findings complement the quantitative results by illustrating distinct reasoning patterns across students with high, medium, and low prior ability. As shown in Table 4, students were distributed across the three categories proportionally. HOTS analysis was carried out using open coding aligned with the indicators shown in Table 5.

Table 4. Distribution of Students' Prior Ability Levels

Category	N	Percentage
High	3	18.75%
Medium	8	50%
Low	5	31.25%

Table 5. HOTS Indicators Used in Qualitative Analysis (Scope: Real Number)

Indicator	Cognitive Level	Description
Formulating proof models	C6	Constructing abstract representations
Critiquing proof stages	C5	Evaluating logic within a proof
Solving proof based tasks	C6	Generating complete mathematical arguments

Qualitative analysis of the high ability student revealed strong conceptual grounding and the ability to translate verbal statements into formal symbolic structures. The student demonstrated coherent use of proof by contradiction, and the reasoning sequence satisfied all HOTS indicators. A placeholder image representing student work is provided in Figure 1.

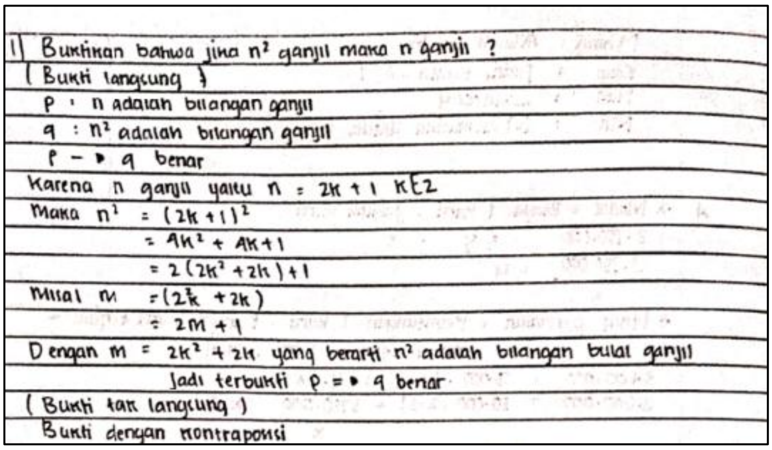

Figure 1. High ability student response

Students classified as having medium prior ability demonstrated correct procedural reasoning and could construct valid models of odd numbers, but their explanations occasionally lacked depth. They showed clear progression after receiving scaffolded prompts through dynamic assessment. A representative placeholder is shown in Figure 2.

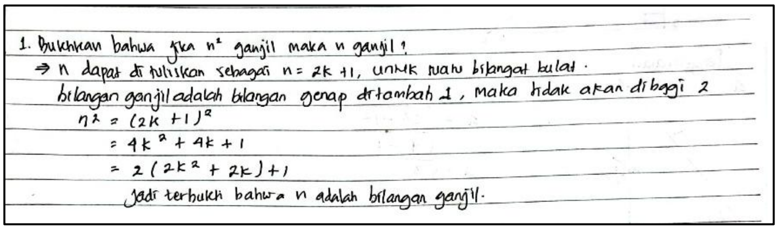
1. Buktikan bahwa jika n^2 ganjil maka n ganjil!
⇒ n dapat di tuliskan sebagai $n = 2k + 1$, untuk suatu bilangan bulat.
bilangan ganjil adalah bilangan genap ditambah 1, maka tidak akan dibagi 2
$n^2 = (2k+1)^2$
$= 4k^2 + 4k + 1$
$= 2(2k^2 + 2k) + 1$
Jadi terbukti bahwa n adalah bilangan ganjil.

Figure 2. Medium ability student response

Meanwhile, low ability students provided incomplete reasoning, often presenting direct answers without connecting them to general mathematical structures. Although their work showed emerging understanding, it lacked the abstraction required for C5–C6 performance. Dynamic assessment helped identify misconceptions early and supported incremental progress. Figure 5 provides a placeholder for student work from this group.

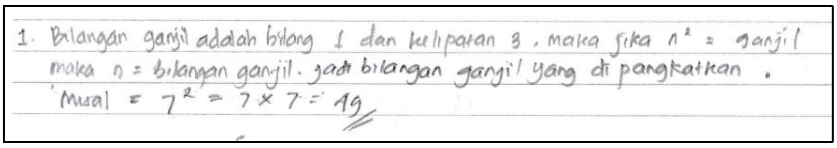
1. Bilangan ganjil adalah bilang 1 dan kelipatan 3, maka jika n^2 = ganjil
maka n = bilangan ganjil. jadi bilangan ganjil yang di pangkatkan.
Misal = $7^2 = 7 \times 7 = 49$

Figure 3. Low-ability student response

The findings of this study demonstrate that the integration of the TPACK based Flipped Classroom model with dynamic assessment effectively strengthens the higher order thinking skills of prospective mathematics teachers. The pattern of increasing activity observed across the six instructional meetings reflects how students gradually internalized the learning structure: initial content familiarization occurred through pre class TPACK aligned digital materials, while higher level cognitive processing was emphasized during class through collaborative problem solving and dynamic mediation. This progression is consistent with the theoretical expectation that repeated cycles of preparation and in class reasoning enhance engagement and cognitive performance.

The significant differences identified through the inferential statistical analyses indicate that the instructional model offered cognitive advantages beyond those achieved through conventional lecture based teaching. The large posttest gains in the experimental group support prior research suggesting that Flipped Classroom models are most effective when the technological, pedagogical, and content dimensions are explicitly aligned as articulated in the TPACK framework. The model used in this study extends these principles by embedding dynamic assessment into each instructional stage, transforming assessment from a summative endpoint into a formative, interactive, and diagnostic component.

Dynamic assessment played a particularly important role. Through pre class diagnostic prompts, in class guided questioning, scaffolded hints, and continuous feedback, students' reasoning processes became visible and malleable. These mediated learning interactions, grounded in Vygotsky's sociocultural theory, enabled students to refine their conceptual understanding and correct misconceptions in real time. This form of mediation is especially beneficial in mathematics, where abstract reasoning and proof construction require students to articulate and reorganize their thinking.

Qualitative findings further highlight how the intervention supported learners with varying initial abilities. High ability students demonstrated sophistication in constructing general proof models, critiquing logical structures, and applying advanced reasoning strategies. Medium ability students showed marked improvement in organizing their ideas and providing more complete justification, illustrating the scaffolding potential of dynamic assessment. Low ability students, while still limited in abstraction, progressed in modeling and interpreting mathematical structures evidence of conceptual shifts facilitated by the interactive assessment features of the model. These differentiated outcomes underline the adaptability of dynamic assessment in heterogeneous classrooms.

Taken together, the results reveal that the synergy of TPACK, Flipped Classroom principles, and dynamic assessment provides a robust and theoretically grounded instructional model for enhancing higher order thinking skills. The model enables students to engage with content in multiple modalities, supports deeper cognitive processing during class, and offers continuous formative mediation tailored to learner needs. This aligns with contemporary calls for teacher education curricula that cultivate analytical reasoning, problem solving, and intellectual autonomy among prospective teachers.

CONCLUSION

This study examined the use of a TPACK based Flipped Classroom model supported by dynamic assessment to enhance higher order thinking skills (HOTS) in mathematics. Findings indicate that the model improved students' HOTS compared with conventional instruction, confirming the effectiveness of combining technology aligned preparation with interactive in class reasoning activities. Quantitative analyses showed clear learning gains for students in the experimental group, while qualitative results demonstrated that students with high and moderate initial abilities were able to articulate mathematical models, justify proof structures, and reason more coherently. Students with lower initial abilities also showed meaningful progression when supported through scaffolded feedback, reflecting the mediational role of dynamic assessment.

Taken together, these outcomes suggest that integrating the TPACK framework, Flipped Classroom design, and dynamic assessment can support the development of higher order reasoning in mathematics education. The study was conducted with a limited sample from a single institution, offering practical implications for mathematics teachers and prospective teachers. The approach encourages instructors to design digital materials that align with pedagogical intentions, allocate classroom time for collaborative problem solving, and incorporate formative assessment strategies that make students' reasoning visible and improvable.

Limitations should be acknowledged. The sample size was relatively small, the study was restricted to one mathematical topic, and the duration of the intervention was limited. Future research may explore longer term implementations, apply the model across diverse mathematical domains, or investigate how dynamic assessment can be optimized for learners with different profiles. Broader, multi site studies could also strengthen the generalizability of the findings.

Results suggest that a TPACK based Flipped Classroom supported by dynamic assessment holds promise as an instructional approach for fostering higher order thinking skills, while further studies are needed to examine its applicability across broader contexts.

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