Cypriot Journal of Educational Sciences

Volume 20, Issue 3, (2025) 163-174

www.cjes.eu

HOTS math analysis in Tpack-based flip classroom learning using dynamic assessment

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Suggested Citation:
Zaeni, A., Kartono & Pujiastuti, E. (2025). HOTS math analysis in Tpack-based flip classroom learning using dynamic assessment. *Cypriot Journal of Educational Science*, *20*(3), 163-174. https://doi.org/10.18844/cjes.v20i3.8525

Received from November 26, 2022; revised from January 23, 2025; accepted from May 21, 2025.
Selection and peer review under the responsibility of Prof. Dr. Hafize Keser, Ankara University, Turkey (retired)

iThenticate Similarity Rate: 1%

Abstract

The development of students' higher-order thinking skills in mathematics remains a critical challenge in educational practice, particularly in adapting to innovative learning models. Previous research has explored flipped classroom approaches and technology integration, yet few studies have examined their effectiveness when combined with dynamic assessment and grounded in the TPACK framework. This study addresses this gap by investigating the impact of a TPACK-based flipped classroom learning model with dynamic assessment on students' higher-order thinking skills in mathematics. A mixed-method design with an embedded concurrent strategy was employed, involving 32 students divided equally into experimental and control groups for the quantitative phase, and three students with different ability levels for the qualitative phase. Quantitative findings indicate that the TPACK-based flipped classroom model enhanced students' mastery of higher-order thinking skills compared to traditional approaches. Qualitative results show that high-ability students demonstrated strong logical reasoning and problem-linking skills, while moderate-ability students applied systematic problem-solving strategies effectively. Low-ability students, however, tended to focus on final answers without fully modeling mathematical conditions. The findings suggest that integrating technology-rich flipped classroom instruction with dynamic assessment fosters deeper mathematical reasoning and provides valuable insights into varying student learning profiles. These results have important implications for designing pedagogical strategies that strengthen critical thinking and problem-solving in mathematics education.

Keywords: dynamic assessment; flipped classroom; higher order thinking skills; mathematics education; TPACK.

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1. INTRODUCTION

High Order Thinking Skills is one of the human resources related to knowledge and skills that must be improved and developed. One indication of success in increasing human resources in the field of education is the large number of candidate teachers who have good higher-order thinking skills (HOTS). Because one of the main goals of learning in the 21st century is to develop and improve HOTS (Tan & Halili, 2015). This is in accordance with the CCEA (Council for Curriculum, Assessment and Examinations) statement, that teachers and practitioners must have some practical guidelines on how to improve students' thinking skills and assess their way of thinking in a constructive way (Walsh et al., 2008).

There are many related studies on HOTS in learning, such as studies on understanding related to HOTS (Dinni, 2018; Rapih & Sutaryadi, 2018), HOTS-based learning designs (Hamidah & Wulandari, 2021; Intan et al., 2020), and evaluations related to HOTS (Dosinaeng et al., 2019; Prastiti et al., 2020; Suratmi et al., 2020). Among all these studies, there are new cases where teachers who understand HOTS well have difficulty choosing a suitable learning model. The fact states that the weak ability of mathematics students as teacher candidates in solving HOTS problems is because they are not used to solving HOTS problems, and they do not develop their higher-order thinking skills when solving problems (Hadi & Faradillah, 2020).

There are several popular learning models used in TPACK-based development research, such as the Flipped Classroom. This model combines face-to-face learning and online learning. For online learning purposes, a teacher or lecturer can create their own blog and website or use existing blogs and websites (Pasani, 2018). Flipped Classroom is blended learning (face-to-face and online learning) that combines synchronous learning with asynchronous independent learning. Synchronous learning is usually carried out in the classroom in real time. Students interact with a teacher and classmates, then receive feedback at the same time. Meanwhile, asynchronous learning is learning that students tend to do independently. Learning content can usually be accessed through several media on digital platforms. Students can choose their own study time, ask questions in the comments session, and share ideas or insights with teachers or other students. In asynchronous learning, feedback is usually not received at the same time (Bhagat et al., 2016).

Video is a medium that is often used as input for self-study because it can be accessed at any time and allows students to stop and re-watch content as needed. Text and audio can also be used to convey content and ensure students are fully prepared for synchronous classes. The teacher plays an important role in the learning process whose job is to encourage, guide, and provide learning facilities for students to obtain the expected learning outcomes (Fitri & Zaeni, 2020). In this era of globalization, students as candidate teachers need to master the ability to think critically, creatively, innovatively, logically, and systematically in communicating ideas or solving problems so that students are able to develop their thinking skills in solving everyday problems (Lestari, 2014; Zhao et al., 2021).

Today's teachers need to pay attention to basic important aspects such as the use of technology. Technology can be used as a tool to create meaningful experiences in the learning process (Weigand et al., 2024; Zhao et al., 2024). An example of using technology in learning is to apply the flipped classroom concept. According to Bergmann & Sams (2012), the flipped classroom method is an innovative pedagogical approach that focuses on student-centered learning by reversing the traditional classroom learning system conducted by teachers. This flipped classroom method has many benefits, such as students having positive opinions and an open attitude to new knowledge. Students also become more active, independent, creative, and critical in addressing certain problems (Porcaro et al., 2016).

Based on the previous explanation, it can be asserted that TPACK-based learning is an appropriate learning model for solving problems related to HOTS in mathematics students as prospective teachers. TPACK makes learning more effective and efficient; therefore, a professional teacher must have TPACK competence. In addition, TPACK competencies are also included in the four competencies that must be possessed by a teacher, such as pedagogic, personality, social, and professional. Therefore, the pattern of developing teacher competence by utilizing the TPACK strategy is an attempt to guarantee the implementation of learning that is in accordance with the demands and changes that occur (Suyamto, 2020; Yıldız et al., 2022).

The application of the TPACK-based flip classroom learning model cannot be separated from the assessment of the learning process. Learning assessment includes several steps, such as collecting data on the child's development and learning, determining the importance of the program and considering its goals, incorporating information into planning for individuals and programs, and communicating findings to the child's family and other relevant parties. Assessment of children's progress is integrated with the curriculum and learning.

Assessment is a process of collecting data or information (including processing and documentation) systematically about an attribute, person, or object, either in the form of qualitative or quantitative data about the amount, condition, ability, or progress of an attribute, person, or object being assessed, without referring to value judgment. Learning assessment is an activity to assess or evaluate learning. Assessment is carried out to obtain information about student achievement during learning activities.

Dynamic assessment is an alternative form of assessment that can be bound or connected with other forms of assessment. In this type of assessment, students can be directly involved in the learning process through their own experiences (Gullo, 2014). Dynamic assessment is a type of interactive assessment commonly used in education. Dynamic assessment is a product of research conducted by developmental psychologist Lev Vygotsky. As an alternative assessment modality, it seeks to identify a child's skills and learning potential.

The dynamic assessment procedure emphasizes the learning process and takes into account the number and nature of examiners so that this assessment is highly interactive and process-oriented. One purpose of dynamic assessment is to determine whether a student has the potential to learn a new skill. There are two main approaches to dynamic assessment, namely *Interactionist* and *Interventonist* (Lidz & Gindis, 2003). The dynamic assessment of prospective teachers in this study was carried out by following the flow of student habits. While researchers monitor the development of students according to their respective abilities. This is in accordance with the principle of dynamic assessment, which focuses on students' ability to avoid teacher intervention.

1.1. Literature review

1.1.1. Higher order thinking skills (HOTS)

The theory of higher-order thinking skills (HOTS) is a type of thinking that requires a larger cognitive process than other types of thinking. Brookhart (2010) states that the definition of higher order thinking is categorized into three, namely: transfer knowledge, critical thinking, and problem solving.

a. The definition of higher-order thinking is categorized as Transfer Knowledge

Two of the most important educational goals are retention and transfer of knowledge when learning takes place, which indicates meaningful learning. Retention requires students to remember what they have learned, whereas transfer requires students not only to remember but also to understand and be able to use what they have learned.

b. Definition of Higher Order Thinking categorized as critical thinking

Critical thinking is thinking that is focused when deciding what to believe or do. Brookhart (2010) states that what includes critical thinking, according to Barahal (2008), includes reasoning, questioning, and investigating, observing and describing, comparing and connecting, finding complexity, and exploring viewpoints.

c. The definition of Higher Order Thinking is categorized as problem solving.

The definition of problem solving is categorized into two, namely:

1) A student encounters a problem when he wants to achieve a certain result or goal, that is, he does not automatically recognize the path or method used to achieve that result. The problems he faces make him achieve the desired goals, because these students cannot automatically recognize the right way to achieve the desired goals. Therefore, he must use one or more higher-order thought processes. These thinking processes are called problem-solving.

2) Problem-solving is a model that can be applied to each problem in helping a person continue to learn on their own, as well as developing the necessary automatic strategies to achieve a goal. A similar tone was stated by Bass et al. (2012), that higher-order thinking skills include the concepts of critical thinking, problem solving, creative thinking, and decision making. In addition, Conklin (2012) & Heong et al. (2011) stated that higher-order thinking skills include critical thinking and creative thinking. In the revision of Bloom's taxonomy, the cognitive processes that occur when students are active are analyzing, evaluating, and creating (Conklin, 2012). This cognitive process can increase students' higher-order thinking. More broadly, higher-order thinking skills are defined in it, including critical, logical, reflective, metacognition, and creative thinking (King et al., 1998). All of these abilities are active when a person is faced with unfamiliar problems, uncertainties, questions, and choices. Higher-order thinking skills are not only applied at school, but also applied in real life (Williams, 2003).

A student is said to be able to solve problems if he can apply previously acquired knowledge to new, unfamiliar situations. This ability is known as higher-order thinking skills (Setiawan & Lestari, 2014). This ability is the most difficult ability to cultivate students' thinking at school, because this ability is beyond traditional learning steps (Goethals, 2013). From the definitions above, it can be concluded that higher-order thinking skills are thinking skills that include critical thinking and creative thinking, which are obtained through the cognitive process of analyzing, evaluating, and creating.

1.1.2. Tpack-based flip classroom

Flipped Classroom is a model in which the teaching and learning process is not as usual, namely, in the learning process,/students study subject matter at home before lectures begin, and teaching and learning activities in class are in the form of doing assignments, discussing material, or problems that are not yet understood. By doing assignments in class, it is hoped that when students experience difficulties, they can immediately consult with their friends or with the lecturer so that the problem can be solved immediately.

The flipped classroom method is divided into three activities, namely, before class starts (pre-class), when class starts (in-class), and after class ends (out of class). Before class begins, students have studied the material to be discussed. In this stage, the abilities that are expected to be possessed by students are remembering and understanding the material. Thus, when class begins, students can apply (applying) and analyze (analyzing) material through various interactive activities in class, which are then followed by evaluating (evaluating) and working on certain project-based tasks as activities after class ends (creating).

The series of processes above is related to the flipped classroom with Bloom's Taxonomy, which is explained in Figure 3 below. There are several sections, namely Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating, which are divided into three activities, namely before, during, and after class. The aspect of using technology is a fundamental thing that teachers need to pay attention to in the current era, but that's not everything; technology is a tool that can be used to create meaningful experiences in the teaching and learning process.

This can be achieved by applying the flipped classroom concept. According to Bergmann & Sam (2012), the flipped classroom method is an innovative pedagogical approach that focuses on student-centered teaching by reversing the traditional classroom learning system that has been carried out by teachers so far. The flipped classroom method does have many benefits (McLaughlin et al., 2014), such as students will have positive opinions and be open to new knowledge, be more active, more independent, and creative, and be more critical in addressing specific case problems. Based on the explanation above, it can be said that the flipped classroom is very suitable if it is integrated with TPACK.

Flipped Classroom is a form of blended learning (through face-to-face and virtual/online interactions) that combines synchronous learning with asynchronous independent learning. Synchronous learning usually occurs in real time in the classroom. Students interact with a teacher and classmates and receive feedback at the same time (Chen et al., 2025). Meanwhile, asynchronous learning is learning that is more independent. Content is usually accessed through some form of media on digital platforms. Students can choose when they study, and they can also ask questions in the comments column and share their ideas or understanding of the material with teachers or classmates. Meanwhile, feedback will be received by them at the same time.

1.1.3. Dynamic assessment

Dynamic assessment is an assessment that is carried out without being bound by a time pattern. Researchers continue to carry out assessments, measurements, and evaluations throughout the development of students in the learning process. Each assessment result becomes the baseline for the next assessment. Dynamic assessment is an alternative form of assessment that can be tied to other forms of assessment. In this type of assessment, the child is directly involved in the learning process, using experiential mediated learning (Gullo, 2014). Dynamic assessment is a kind of interactive assessment used in education and the auxiliary professions.

Dynamic assessment is also a product of research conducted by developmental psychologist Vygotsky (1986). As an alternative assessment modality, it seeks to identify the skills a child has and their learning potential. The dynamic assessment procedure emphasizes the learning process and takes into account the amount and nature of the testers' investment. It is very interactive and process-oriented. One purpose of dynamic assessment is to determine whether a student has the potential to learn a new skill. There are two main approaches to DA: Interactionist and Interventonist (Lidz & Gindis, 2003). The learning experience dimension is defined as the interaction occurring between the assessor and the child. The assessor mediates the environment for the child through appropriate framing, selection, focusing, and provision of feedback. The assessor reinforces the experience previously acquired by the child. The purpose of posing this is to produce proper learning systems and routines for the child. Actual curriculum activities consist of assessment tasks presented to children. Dynamic assessment is a procedure devised by Reuven Feuerstein et al., (1986) and based on the theory by Vygotsky (1986, 1987).

1.2. Purpose of study

The purpose of this study was to investigate the effectiveness of a TPACK-based flipped classroom learning model integrated with dynamic assessment in enhancing students' higher-order thinking skills (HOTS) in mathematics. By combining technology-supported instruction with interactive assessment, the study aimed to provide insights into how this approach influences students' mathematical reasoning across different ability levels and contributes to the development of more effective pedagogical strategies in mathematics education.

2. METHODS AND MATERIALS

The type of research used is mixed method research (a mixture of quantitative and qualitative), with the mixed method research design used being an embedded concurrent design. This design can also be characterized as a mixed methods strategy that employs one stage of both quantitative and qualitative data collection at a time. In this design, when a researcher compares one data source with another, two data processes occur. This processing usually occurs frequently in the discussion section of the survey. However, rather than comparing two datasets, they should be drawn side by side as two separate images that represent a combined assessment of the problem. (Creswell & Creswell, 2017).

2.1. Data collection instruments

This study will combine two forms of research, namely quantitative and qualitative research. In the quantitative test, the researcher will collect data from 2 experimental and control classes.

2.2. Participants

In this study, class A is the control class using conventional learning, and class B is the experimental class with flip classroom learning based on TPACK using dynamic assessment. Whereas in the qualitative test, the researcher grouped the experimental student responses into high, medium, and low percentages, then the researcher took 1 student from each criterion as the subject of qualitative analysis by documenting the student's answers.

3. RESULTS

3.1. TPACK-based flipped classroom learning using dynamic assessment

Results and Discussion of TPACK-Based Flipped Classroom Learning Using Dynamic Assessment are as follows:

Table 1

Analysis of student activities in TPACK-based flipped classroom learning using dynamic assessment

Number of students	3rd meeting						Post Test
	1	2	3	4	5	6	
32	70%	75%	75%	80%	87%	90%	TEST HOTS

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

3.2. Mathematics HOTS analysis

3.2.1. Quantitative analysis

In quantitative analysis, the researcher produced an analytical test as follows.

Table 2

Quantitative analysis results

Test	hypothesis	Sig. Value	Results
Normality test	h0: normally distributed h1: not normally distributed	0,132 (A) 0.200 (B)	H0 is accepted
Homogeneity Test	h0: homogeneous data h1: data is not homogeneous	0,207	H0 is accepted
One-sample T-test	h0: no significant difference between Grade A and B math HOTs h1: There is a significant difference between Class A and B mathematics HOTs	0,000	H0 is accepted

Based on the results of the analysis presented in Table 2, it can be stated that classes A (Control) and B (Experimental) are normally distributed with a significance value of 0.132 (A) and 0.200 (B), respectively. The data is called normal if the significance value is greater than 0.05. Likewise, the homogeneity significance value is 0.207. So it can be stated as homogeneous. The one-sample t-test is a sample test that aims to find out whether there are differences in the HOTs of students using TPACK-based flip classroom learning and conventional learning. In this analysis, the value of the one-sample t-test is less than 0.05, so that it can be said that there is a significant difference between the HOTs of mathematics Class A (Control) and B (Experiment).

3.2.2. Qualitative analysis

The results of the student's initial ability data are used to determine the research subject before being given treatment in a class that uses flipped classroom learning with the dynamic assessment-assisted TPACK approach. Obtained student grouping data, which is presented in the following table:

Table 3

Student initial ability test criteria

Initial ability test criteria	Lots of Students	Percentage
Tall	3	18,75%
Currently	8	50,00%
Low	5	31,25%
Amount	16	100 %

Based on the table of criteria 9table 3), it is observed that the criteria for high are 18.75%, medium are 50%, and low are 31.25%. This value is determined based on the criteria for scoring, followed by a qualitative analysis process from the representatives of each criterion, with the following indicators:

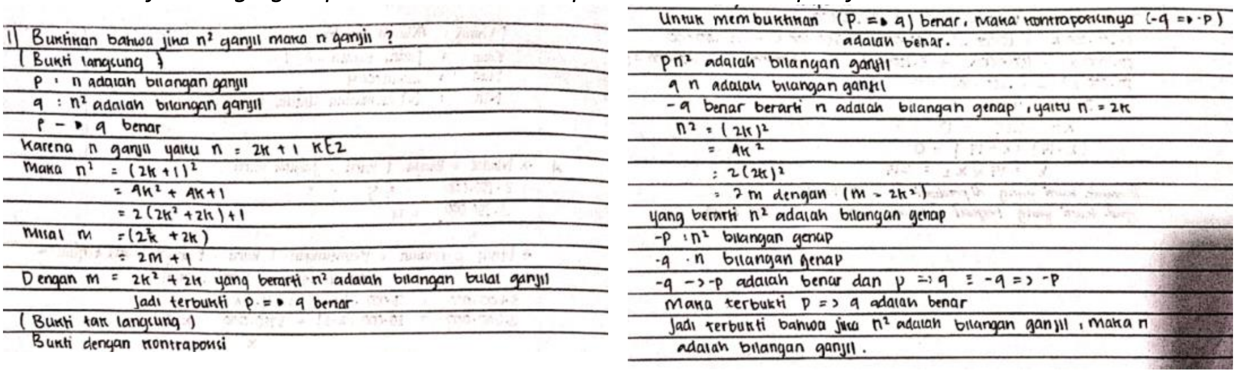
Table 4
HOTS indicators

Material Scope	Indicator
Real Numbers	Formulate real number proof solutions (C6) Criticizing the stages of completing the proof of real numbers (C5) Solving problems with the mathematical proof method (C6)

In the following, the researcher presents the results of the analysis based on the indicators that have been set.

a. HOT's analysis of student mathematics in the high group

Figure 1
Answers from high group students on HOTS questions in the scope of real numbers

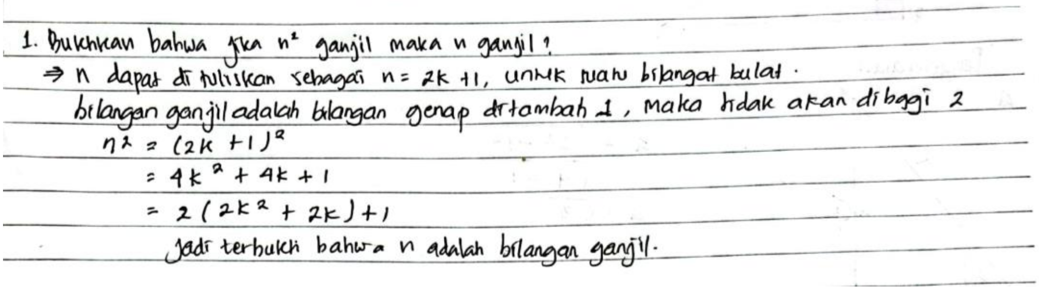


The results of the analysis of student answers with high criteria show that students can define odd numbers in the form of a mathematical model and can prove the method of proving contradictions to get answers. The student presents the correct sequence of completion steps, which leads to the correct answer. So that it can be said to meet HOTS criteria or indicators (Figure 1).

In the analysis of the high group, students are classified as very good, as shown in Figure 1. Students can write down what is known by using an example, then complete the stages of proof correctly. Based on the results of the interviews, information was obtained that students defined odd numbers by linking mathematical concepts that they had studied before; besides that, students were able to present the problem in an equation, with both direct and indirect evidence.

b. Analysis of student mathematics HOTs in the medium group analysis of student mathematics HOTs in the medium group

Figure 2
Answers of students in the medium group HOTS questions with the scope of real numbers



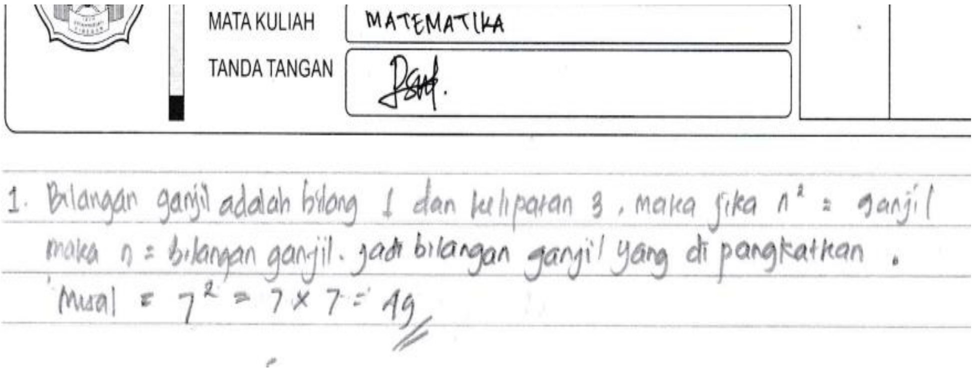
The results of the analysis of these answers show that students can define odd numbers in the form of a mathematical model. According to Hamidy and Jailani (2019), solving problems in the form of mathematical models requires the ability to think creatively. The student's answer presents the correct sequence of completion steps and leads to the correct answer. So that it can be said to meet HOTS criteria or indicators.

In the analysis of the medium group, students can provide a logical explanation by showing evidence in Figure 2. Students are able to put forward a solution to a problem by defining an odd number in the form of an equation first, then compiling the steps to prove it. In this section, students feel that there is no difficulty in finding and determining evidence. This can be seen from the work on the students' answer sheets, where students can complete properly, completely, and systematically. When interviewed, students can also answer the questions given clearly and precisely. Through the use of language/symbols/formal/technical and arithmetic operations, students can find out the relationship between problems and solutions that must be found. Students already understand the workmanship of the questions asked, so they have good HOTS skills.

c. Analysis of student mathematics HOTs in the Medium Group

Figure 3

Low group students' answers to HOTS questions in the scope of real numbers


MATA KULIAH MATEMATIKA
TANDA TANGAN

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 = $7^2 = 7 \times 7 = 49$

Student answers in Figure 3 indicate that student HOTS is low, namely, students are unable to model odd numbers and cannot formulate solutions into general mathematical forms.

In the analysis of students in the Low group, students immediately answer without linking it to mathematical modeling, and there is no explanation of what results have been obtained. Based on this, it can be concluded that these students are sufficient in restating a problem in proof without defining mathematical symbols/models. In the results of the interviews, students were able to state what was known and asked, even though when asked about the method/strategy, students found it a little difficult. Based on these conditions, students are still quite good at HOTS.

4. DISCUSSION

The findings of this study demonstrate that the integration of a TPACK-based flipped classroom with dynamic assessment effectively enhances the higher-order thinking skills (HOTS) of mathematics student teachers. Quantitative analysis revealed significant differences between the experimental group and the control group, while qualitative analysis showed that students across high, medium, and low achievement levels exhibited measurable improvements in their ability to formulate, critique, and solve mathematical problems. These findings provide meaningful contributions to the ongoing discourse on teacher education and innovative pedagogical strategies.

The positive effects observed align with previous studies emphasizing the importance of HOTS as a key competency for 21st-century learners. For instance, Tan and Halili (2015) highlighted that developing HOTS is central to modern education, and our findings corroborate this by demonstrating that structured interventions can yield significant gains in students' analytical and problem-solving abilities. Similarly, the observation that students initially struggle with HOTS tasks but improve with practice resonates with Hadi and Faradillah's (2020) conclusion that students' limited exposure to HOTS problems hinders their problem-solving ability. In our study, the flipped classroom supported by TPACK and dynamic assessment provided repeated opportunities for engagement, allowing students to gradually internalize higher-order processes.

Our results also reinforce previous findings regarding the pedagogical value of flipped classrooms. Bergmann and Sams (2012), McLaughlin et al. (2014), and Porcaro et al. (2016) reported that flipped learning increases student engagement, independence, and critical thinking. In line with these studies, we found that student activity levels steadily rose from 70% at the outset to 90% by the final session, demonstrating increased responsibility for learning. Furthermore, Bhagat et al. (2016) emphasized the role of asynchronous and synchronous elements in supporting self-paced learning. This was evident in our context, as students benefited from pre-class digital materials that facilitated deeper classroom discussions.

The integration of TPACK competencies into flipped classroom instruction was also consistent with prior research. Pasani (2018) and Suyamto (2020) argued that the mastery of TPACK enhances teachers' capacity to deliver effective, technology-mediated instruction. Our findings extend this evidence by showing that when TPACK is coupled with dynamic assessment, it not only supports teaching efficiency but also directly impacts the development of students' HOTS. This dual contribution—improving pedagogy and student outcomes—suggests that TPACK-based flipped classrooms are particularly well-suited for teacher preparation programs.

The use of dynamic assessment adds a unique dimension to this study. While earlier works (Gullo, 2014; Lidz & Gindis, 2003) emphasized the interactive and process-oriented nature of dynamic assessment, our findings illustrate its potential when combined with flipped learning. The continuous monitoring of students' problem-solving approaches provided richer insights than static assessments, allowing teachers to scaffold students' development more effectively. Compared to traditional summative assessments, this dynamic model fostered reflective engagement, especially for medium- and low-achieving students who benefited from ongoing feedback and guided exploration.

Despite the overall alignment with previous studies, our results also suggest some divergences. For instance, while Dosinaeng et al. (2019) and Prastiti et al. (2020) focused on evaluation frameworks for HOTS, they did not explicitly address how assessment could be embedded within instructional models. Our findings fill this gap by demonstrating that assessment is not merely evaluative but can be integral to the learning process itself. Similarly, while Fitri and Zaeni (2020) emphasized the teacher's role as facilitator, our study indicates that technology-supported models shift some of the cognitive responsibility toward students, requiring teachers to adopt new roles as mediators rather than sole sources of knowledge.

5. CONCLUSION

Taken together, the findings contribute to a growing consensus that developing HOTS requires more than exposure to challenging problems; it demands pedagogical designs that integrate technology, active learning, and formative assessment. By showing that a TPACK-based flipped classroom with dynamic assessment can significantly enhance student teachers' mathematical reasoning, this study provides a practical pathway for improving teacher preparation in mathematics education.

Future research could build on these results by exploring longitudinal effects of this model across multiple courses, or by investigating how different components of TPACK (technological, pedagogical, and content knowledge) uniquely interact with dynamic assessment in fostering HOTS. Additionally, examining the scalability of this approach in diverse educational contexts would help determine its broader applicability.

Based on the results and discussion in this study, it can be concluded that 1). HOTS mathematics for students in a flipped classroom learning using dynamic assessment is better than learning in a conventional class with problem-based learning (PBL) models. 2) Students' HOTS mathematics in a flipped classroom learning using dynamic assessment can solve HOTS mathematics problems more precisely.

Conflict of interest: No potential conflict of interest was reported by the authors.

Ethical Approval: The study adheres to the ethical guidelines for conducting research.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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