

# Does the Hybrid Microteaching Model Improve TPACK Competence? Empirical Evidence from Pre-Service Teachers

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## Abstract

This study aims to develop and test the effectiveness of the Hybrid Microteaching Model in improving the Technological Pedagogical Content Knowledge (TPACK) competence of prospective Islamic Education teachers in Indonesia. Using the Borg & Gall research and development method, the model was designed by integrating synchronous online and offline learning to overcome the limitations of conventional microteaching. The validity of the model was assessed by experts using Aiken's V, while its effectiveness was tested using a quasi-experimental design with pre-tests and post-tests in the experimental and control classes. Limited trials involving 10 students showed an increase in TPACK scores from an average of 97.2 to 198.1, with a significant difference ( $t = -9.909$ ;  $p < 0.05$ ). Extensive trials showed an increase from 132.91 to 165.86 (a difference of 32.95 points, significant). In the experimental class, the score increased from 66.2 to 87.5 (a difference of 21.3 points,  $p = 0.000$ ), while the control class only increased from 65.4 to 74.8 (a difference of 9.4 points,  $p = 0.692$ , not significant). These data confirm that the Hybrid Microteaching model is more effective than conventional methods. Practically, this model helps prospective teachers integrate technology, pedagogy, and content into 21st-century teaching practices. Theoretically, this research expands the application of the TPACK framework by adding the context of synchronous digital technology integration in Islamic education.

**Keywords:** Hybrid Microteaching, Instructional Development, Islamic Education, Pre-Service Teachers, TPACK.

## Introduction

The development of the Industrial Revolution 4.0 and society 5.0 has affected almost all aspects of life, including education, which now requires a transformation of the teaching paradigm towards a technology-based learning model. Teachers no longer merely act as conveyors of information, but also as facilitators, innovators, and developers of learning experiences who are able to integrate technology into learning practices (1, 2). In the 21st century educational landscape, the ability to integrate content, pedagogy, and technology is a key competency that prospective teachers must have. Therefore, Technological Pedagogical Content Knowledge (TPACK) becomes a very important conceptual framework in designing and evaluating teacher competencies in the digital context (3, 4). This concept emphasizes the importance of synthesizing content knowledge (CK), pedagogical knowledge (PK), and technology knowledge (TK) in an integrative manner to make the learning process more meaningful, adaptive, and contextual. Previous studies have shown that mastery of TPACK has a positive correlation to

improving teaching quality and learner learning outcomes (5). In this context, strengthening TPACK at the prospective teacher education level is a strategic need in preparing educators who are able to answer future challenges. Unfortunately, in many educational institutions (LPTK), especially in study programs that produce prospective teachers, the implementation of learning that supports the strengthening of TPACK is far from optimal. One prominent weakness lies in the implementation of microteaching, which is still dominated by conventional approaches. Microteaching as a vehicle for training basic teaching skills is often limited to face-to-face practice in classrooms with simple media, such as whiteboards and manual worksheets (6). This approach does not provide a learning experience that is in line with the digital ecosystem that is now an integral part of the educational reality. Microteaching activities should be a simulation space that is able to prepare prospective teachers to face today's classrooms, which are complex, digitized, and demand high techno pedagogical abilities (7). However, the lack

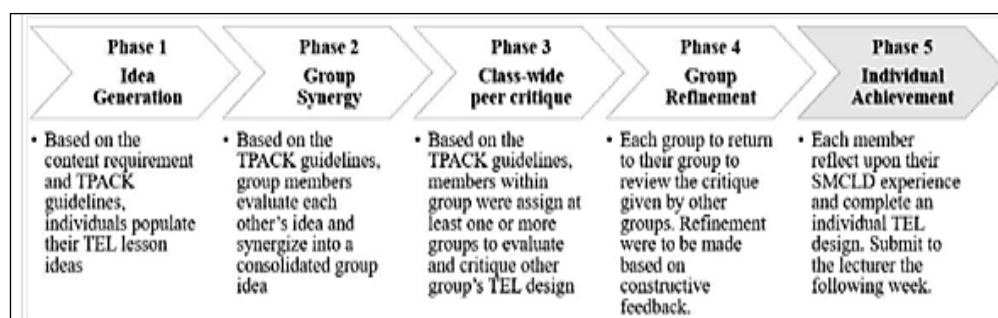
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of technology integration in microteaching causes the TPACK competencies that are formed tend to be incomplete, especially in the TK and TPK aspects. This is exacerbated by limited resources, low technological literacy of lecturers, and the absence of a practice learning model that is adaptive to the dynamics of the times.

Several studies have attempted to offer solutions to these problems, especially through the use of blended learning models or online microteaching. It has been reported that the use of digital media in online microteaching increased student participation and confidence (8, 9). However, the approach did not incorporate systemic aspects such as alignment of learning objectives, assessment strategies, and technology integration across all phases of the lesson. It also did not evaluate comprehensively its impact on each TPACK domain. Other studies developed interactive video media for microteaching, but their effectiveness in strengthening the simultaneous integration of content, pedagogy, and technology was not examined in depth.

Another study attempted to improve teachers' TPACK skills using web media. The model is the Spiral Model of Collaborative Lesson Design (SMCLD), an innovative collaboration-based approach designed to improve Technological Pedagogical Content Knowledge (TPACK) competencies in prospective teachers visualized in Figure 1 (10). This model facilitates the learning process through five structured phases, starting from individual idea development, group synergy, inter-group critique, idea refinement, to individual reflection and achievement. Through these systematic stages, participants are encouraged to exchange ideas, provide constructive feedback, and build more meaningful technology-based learning designs. The results show that participation in SMCLD is able to improve participants' ability to integrate technology, pedagogy and content effectively in the context of 21st century learning. With externally scripted learning scenarios, the model is proven to significantly optimize the collaborative potential in prospective teachers' professional development.



**Figure 1:** Existing Model Spiral Model of Collaborative Lesson Design (SMCLD) (10)

Although the Spiral Model of Collaborative Lesson Design (SMCLD) has proven to be effective in improving prospective teachers' TPACK competencies, the model still has some limitations. First, SMCLD is designed for face-to-face learning contexts with the support of web-based collaborative boards, so its application in fully online learning is not optimal without adequate integration of a learning management system (LMS). This gap emphasizes the importance of developing a microteaching model that not only functions as a space for practicing teaching skills, but also as a learning ecosystem that reflects the real challenges of the digital classroom. This need is becoming increasingly urgent for all teacher study programs, without exception, which so far do not have flexible, adaptive, and contextual model

tools. Especially in the post-pandemic era, hybrid learning approaches and the use of real-time technology are strategic solutions to overcome space and time limitations in the teaching practice process (11, 12).

Therefore, the development of a synchronous-based hybrid microteaching model is a relevant alternative to bridge the disconnect between conventional practices and the demands of digital learning. This model needs to be designed to enable real, collaborative, and techno pedagogically immersive teaching simulation experiences.

This study aims to develop and test the effectiveness of a synchronous-based Hybrid Microteaching Model to improve prospective teachers' TPACK competencies. The model was

designed through a Research and Development (R and D) approach based on steps from Borg and Gall, including preliminary studies, product design, expert validation, limited trials, and effectiveness testing using a quasi-experiment design. The integration of technological tools such as LMS, AI-based applications (Quizizz, Kahoot), and AR media (Assemblr Edu) is used to create an interactive, flexible, and appropriate learning atmosphere in today's digital context. TPACK competency assessment is conducted through indicator-based pretests and posttests that refer to Mishra and Koehler's theory (3). With this method, the research is expected to not only produce a valid and practical learning model, but also prove effective in shaping competencies that are in line with contemporary learning needs.

The novelty of this research lies in the systematic design of the Hybrid Microteaching Model that integrates real-time technology into a synchronous learning simulation. The simultaneous use of LMS, AI-based applications (Quizizz, Kahoot), and AR media (Assemblr Edu) provides a unique learning experience not found in previous models. Unlike previous studies that are limited to partial technology adoption, this study combines multiple digital tools in a cohesive framework, supported by empirical evidence from quasi-experimental tests. The contribution of this model is twofold: first, it extends the TPACK theoretical framework in the context of digital micro teaching; second, it offers practical readiness for adoption into the teacher education curriculum in line with the Merdeka Belajar Kampus Merdeka (MBKM) policy. This position underscores the strategic role of this model in reforming TPACK-based microteaching practices for the digital era.

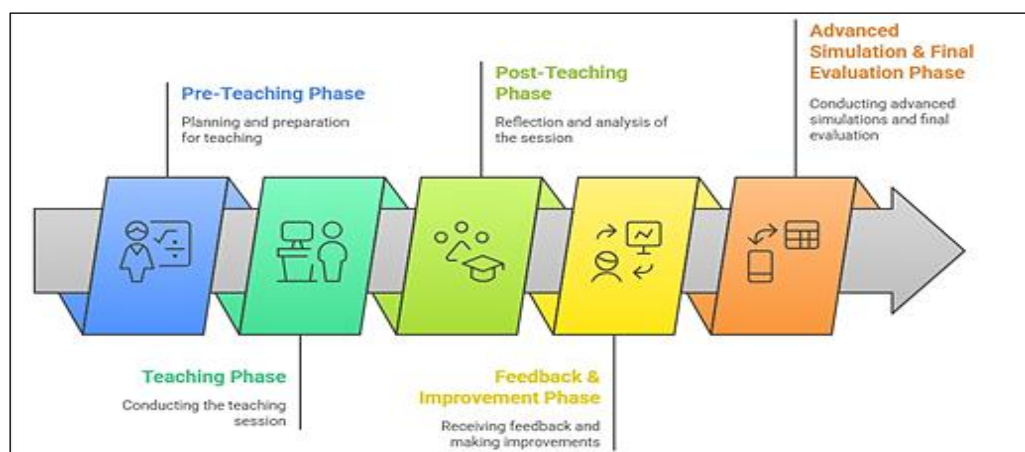
## Methodology

### Research Design

This study used a Research and Development (R and D) approach to develop and validate a Hybrid Microteaching Model aimed at improving the TPACK competencies of student teachers. The development process refers to the modified Borg and Gall model, including six main stages: needs analysis, model design, expert validation, model revision, practicality test, and effectiveness test through quasi-experiment method.

The implementation of the model is carried out through five structured phases. The first phase is the Pre-Teaching Phase, where students access the TPACK-based module through the LMS, develop digital lesson plans with AI-based feedback, and conduct class simulations using AR/VR technology. In the Teaching Phase, students carry out live teaching practice in small groups and broadcast online. Each session is recorded and assessed using the TPACK rubric by lecturers and peers. Furthermore, in the Reflection Phase, students reviewed their microteaching videos with the help of AI analysis, and then discussed asynchronously through the LMS forum.

In the Feedback and Improvement Phase, students revise their teaching strategies based on the video analysis and lecturer feedback. The last phase is Advanced Simulation and Final Evaluation, where students repeat the improved teaching practice and compile a TPACK e-portfolio containing lesson plans, videos, AR media, and reflections. The final evaluation is conducted using rubrics and AI-based instruments. A visualization of this implementation flow is presented in Figure 2.



**Figure 2:** Microteaching Hybrid Model Phases

## Participants and Sampling

Participants in this study were 68 pre-service teachers from one of the teacher education institutions (LPTK) located in Sidoarjo, Indonesia. Using purposive sampling, the participants were divided into two equal groups: an experimental group ( $n = 34$ ), which implemented the hybrid microteaching model and a control group ( $n = 34$ ), which followed conventional microteaching practices. All participants were enrolled in a microteaching course during the sixth semester and had completed foundational courses in pedagogy and educational technology.

The control group followed conventional micro teaching practice, which was conducted through face-to-face teaching simulations in a classroom. Students in this group prepared printed lesson plans and used simple learning media such as whiteboards and worksheets. Teaching practice was conducted in front of peers in short 10-15 minute sessions, and feedback was given verbally by peers and lecturers immediately after the simulation. No video recordings, AI-based feedback, or augmented reality tools were used, and all activities remained within the traditional format of micro teaching. This procedure ensured that the main difference between the control group and the experimental group was the application of the Hybrid Microteaching Model, not the duration of practice or the amount of lecturer supervision.

## Instruments

The instruments used to collect data consisted of: Expert validation sheets, used to assess the model's design, content relevance, and pedagogical alignment. Practicality questionnaires, distributed to both students and instructors to evaluate the usability, clarity, and instructional effectiveness of the model. The TPACK competency test was developed based on predefined indicators from the TPACK framework (3, 5). An initial set of 40 items was created to represent Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), and their intersections. These items were evaluated by a panel of four experts in educational technology, pedagogy, and teacher training to assess content relevance, clarity, and alignment with theoretical constructs. The expert ratings were analysed using Aiken's  $V$ , which yielded values above 0.80 for all items, indicating a

high level of content validity. Construct validity was ensured through expert consensus regarding the fit between the items and the intended TPACK dimensions. A pilot test was then conducted with 30 pre-service teachers to test item discrimination and reliability. After revision and refinement, the final instrument consisted of 30 items, with a Cronbach's Alpha reliability coefficient of 0.81, confirming that the instrument had acceptable internal consistency. The test items were validated and tested for internal consistency, yielding a reliability coefficient (Cronbach's Alpha) of 0.81.

## Data Collection and Analysis

Data collection followed a non-randomized pretest-posttest control group design (13), where both groups completed the same TPACK test before and after the intervention. Quantitative data were analyzed using paired-sample t-tests and independent-sample t-tests to compare intra- and inter-group differences in TPACK gains. Supporting qualitative data from class observations and instructor reflections were analyzed thematically to enrich the interpretation of the model's practicality and classroom dynamics. Ethical clearance was obtained from the faculty, and written informed consent was provided by all participants.

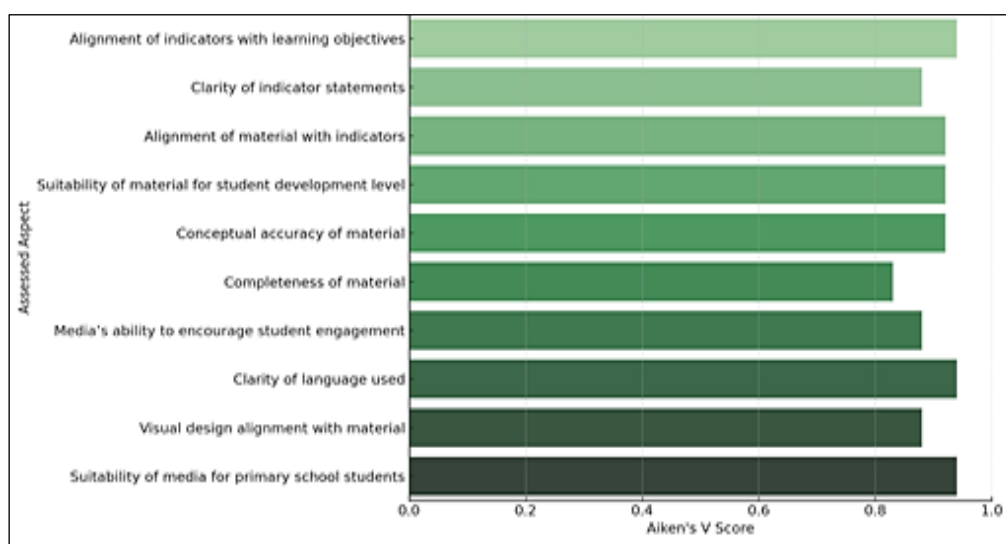
Qualitative data from classroom observations, student reflections, and asynchronous forum discussions on the LMS were analysed using thematic analysis. This process involved three systematic stages: open coding, where meaningful segments of data were identified and labelled; axial coding, where related codes were grouped into categories; and selective coding, where overarching themes were generated. Through this process, three main themes were identified: increased initiative in using digital tools for teaching, increased collaboration and peer support during teaching practice, and deeper reflection facilitated by AI-based feedback. To ensure trustworthiness, triangulation was conducted by comparing data from different sources (observation, reflection, and lecturer notes). In addition, member checking was conducted by sharing thematic summaries with selected participants to ensure accuracy and credibility of interpretations.

## Results and Discussion

### Theoretical Evaluation of Hybrid Microteaching Model through Expert Validation

The initial step in the development of the Hybrid Microteaching Model was carried out through theoretical validation by experts, to ensure that the model design has fulfilled pedagogical, technological, and content principles that are relevant to the needs of today's prospective teachers. Validation was carried out on the model prototype which includes learning syntax, components, and supporting devices in the form of facilitator guides, LKPD, and LMS design. Four experts consisting of education experts, senior lecturers in technology-based learning, and microteaching practitioners were involved in the

validation process using a Likert scale-based assessment sheet. Each aspect of the model was assessed in terms of content suitability, structure clarity, TPACK integration, and technology integration. This validation aims not only to assess the feasibility of the model by design, but also to examine the coherence of pedagogical logic in the context of synchronous hybrid learning. This theoretical evaluation becomes an important foundation before further practicality and effectiveness tests are conducted in an implementative context. The validity of this instrument was further confirmed through expert evaluation, as summarized in Figure 3. This figure presents the Aiken's V values for each aspect of the assessment, which show consistently high values across all indicators.



**Figure 3:** Aiken's V Score for Each Assessed Aspect

The recapitulated results of the experts' assessment showed that all aspects of the model obtained high scores with an overall average value of 4.7 out of a maximum scale of 5. The quantitative results were then analyzed using Aiken's V formula to measure the level of agreement between raters on ordinal evaluation items. The overall Aiken's V value was 0.975, indicating a very high level of content validity and strong consistency of assessment between experts. This indicates that the model design has solid theoretical coherence, and is in accordance with the characteristics of 21st century microteaching learning that systematically integrates technological and pedagogical dimensions. The aspect that received the highest score was the integration of technology

with the flow of learning activities ( $V = 0.98$ ), while the lowest score but still valid was the readability aspect of the guidance document ( $V = 0.92$ ). These values remain in the valid category and are acceptable for the implementation stage.

Qualitatively, the experts provided input for improving the learning syntax and strengthening the integration of technology in the microteaching stages. One important input was the need to affirm the AI-based reflection stage after microteaching practice, in order to strengthen the metacognitive learning of prospective teachers (14, 15). Another suggestion was the use of an LMS that is more flexible and supports two-way synchronous learning, not just a task upload platform. Evaluators also emphasized the importance of

ensuring that the technological component (e.g., the use of augmented reality) is not just a gimmick, but actually support the achievement of learning objectives. This assessment is in line with the literature that emphasizes the need for synchronization between the technology used and the instructional objectives to avoid pedagogical disorientation (16). All of these inputs were used as the basis for revising and refining the model before entering the implementation test stage.

This validation shows that the model design has fulfilled the principle of TPACK theory integration (3), by paying attention to the balance between content, pedagogical, and technological knowledge in the learning process of prospective teachers. The experts' assessment also confirms that this model has the advantage of not only combining online and offline components, but also paying attention to the real teaching dynamics experienced by today's teachers. In this case, theoretical validation has proven that the model is not artificial, but rather designed based on the practical needs of the field synergized with a strong conceptual foundation. The success of this content validation is an initial argument that the model deserves further testing to measure its practicality and empirical effectiveness. This validation stage also emphasizes the commitment to developing a model based on scientific principles, not just technical experiments.

The success of the expert validation process also shows the importance of the collaborative role in instructional design, where the involvement of multi-experts enriches the point of view and strengthens the validity dimensions of the resulting model. This principle is in accordance with the user-centered design approach that prioritizes the involvement of key actors in the process of developing teaching tools, including in the context of teacher education (3). This distinguishes the approach used in this study from previous development models that tend to focus on technical testing without a multiperspective validation stage. By combining quantitative and qualitative validation, the model design becomes more robust and has a strong argumentative foundation to be applied in the field. Expert validation also adds scientific legitimacy to effectiveness claims that will be statistically tested in the next stage.

In addition to being the basis for the field trial step, the results of this theoretical evaluation also make an important contribution to the literature on the development of microteaching learning models in the digital era. While many previous studies have only focused on the use of digital media as a tool in microteaching, this model is designed as a complete learning system, with a learning logic that represents the dynamics of a hybrid classroom. This provides a significant differentiator in the world of TPACK-based learning research, as it positions technology not just as a tool, but as part of the epistemological framework of learning itself. In this context, theoretical evaluation through expert validation not only ensures design quality, but also makes a scientific contribution to the expansion of the TPACK-based learning model development framework.

### **Model Practicality**

After being declared theoretically valid, the next step is to test the practicality of the Hybrid Microteaching Model in the actual learning context. The practicality test was carried out through limited implementation of the model on a group of students who were taking microteaching courses, as well as through observations and feedback from the lecturers. The purpose of this test is to determine the extent to which the model can be applied effectively in real situations, including ease of use, smooth learning flow, and user response to integrated digital features. As shown by the results of related research, a learning model is said to be practical if it can be operated easily by target users and can support the achievement of learning objectives. In this study, practicality was evaluated using a Likert scale questionnaire distributed to 34 students and 2 lecturers. This instrument covers seven main aspects that reflect the overall operational function of the model.

Data from students' responses showed that the majority of the aspects received positive responses above 80%, indicating that this model has a high level of applicability. The aspect with the highest score was "ease of access to LMS and digital media" at 88.2%, followed by "benefits of real-time feedback features (AI)" at 86.8%, and "ease of use of the model" at 85.3% (see Table Perception of Practicality of Hybrid Microteaching Model). This shows that students can follow the learning flow comfortably and efficiently, without being



constrained by technical barriers or procedural confusion. Lecturers also stated that this model makes it easier to supervise because student performance data can be monitored directly through the prepared LMS system. In fact, automatic feedback from the AI-based system can

be used as students' initial reflection before the face-to-face discussion session. This finding is in line with the principle of digital learning based on the integration of real-time learning analytics to support adaptive and responsive learning (17).

**Table 1:** Summary of Pre-test and Post-test TPACK Scores

| Group        | N  | Pre-test Mean<br>(SD) | Post-test Mean<br>(SD) | Mean<br>Difference | t-value | p-value |
|--------------|----|-----------------------|------------------------|--------------------|---------|---------|
| Experimental | 34 | 132.91 ( $\pm 12.4$ ) | 165.86 ( $\pm 14.2$ )  | +32.95             | -9.909  | 0.000*  |
| Control      | 34 | 65.4 ( $\pm 10.7$ )   | 74.8 ( $\pm 11.3$ )    | +9.4               | -0.398  | 0.692   |

The quantitative data can be seen in Table 1 which shows the results of the pretest and posttest. The practicality of the model is also reflected in the flexibility of learning time and place, with 82.5% of students stating that they feel freer in accessing materials, organizing practice schedules, and managing reflection time. The model allows teaching simulation sessions to be conducted in a hybrid manner, where students can choose to perform live or synchronously online. This capability is very relevant to today's demands where learning does not always take place within the confines of physical space (18). In addition, the modularly designed microteaching syntax flow helps students understand the step-by-step learning process, from planning, implementation, to reflection, as indicated by 84.7% positive response rate. Thus, this model not only facilitates the learning process, but also clarifies the learning structure itself.

From the lecturer's perspective, practicality can be seen in the system's ability to automatically summarize student performance through the LMS dashboard. This makes it easier for lecturers to provide formative and data-based feedback. In fact, lecturers stated that compared to conventional microteaching models that rely on manual notes and direct observation, this model is much more efficient in reporting and making learning decisions. This practicality also reduces the administrative burden of lecturers so that more time can be allocated to the process of mentoring and reinforcing reflection. A previous study showed that high practicality in digital learning models increases the chances of adoption by educators as it adds value in work efficiency and interaction quality (19). Therefore, the practicality of this model is not only in terms of technical

implementation, but also in supporting the work system of lecturers in managing practical learning. Another important aspect that was considered practical by students was the suitability of the model to the needs of field practice, where 83.9% of respondents considered that this model helped them prepare the teaching skills needed in real life at school. Features such as the uploading of practice videos, peer-to-peer comments through the discussion forum, and monitoring of learning activities in the LMS dashboard provide a learning experience similar to the actual learning environment. In fact, through the use of Augmented Reality (AR), students can simulate classroom conditions with virtual interaction of learning objects. This approach allows for more contextualized, flexible and authentic learning. Within the framework of digital constructivism, such learning experiences strengthen students' ability to make situation-based instructional decisions (20, 21). In other words, the practicality of this model is not only mechanical, but also conceptual in supporting students' pedagogical skills.

The qualitative data supported the quantitative findings. Students in the experimental group reported greater initiative and confidence when using the digital media. One student reflected, "I became more confident after practicing with the AR media because it felt like a real classroom." Another student noted, "The AI feedback helped me identify mistakes that I was not aware of, such as pacing and voice clarity." Lecturer observations also confirmed that students were more proactive in designing interactive lesson plans and providing feedback from their peers through the LMS discussion forum. From all these results, it can be concluded that the Hybrid Microteaching Model has a high level of practicality, both from the

perspective of students and lecturers. This model is able to answer the challenges of today's practical learning that requires a learning system that is not only pedagogically effective, but also technologically efficient and operationally flexible. With a combination of digital features such as LMS, AI feedback, and synchronous video streaming, as well as a modular and open learning structure, this model is one of the alternative solutions for LPTK in organizing applicable TPACK-based teaching practice. This practicality strengthens the model's implementative foundation for the next stage, which is the effectiveness test that will examine its direct effect on improving prospective teachers' competencies quantitatively.

### **Model Effectiveness on TPACK Ability**

After the validation and practicality stages, this research entered the most critical stage, namely testing the effectiveness of the model empirically on the Technological Pedagogical Content Knowledge (TPACK) abilities of prospective teachers. The test was conducted using a quasi-experimental design with a pretest-posttest control group format, where the experimental group received treatment using the Hybrid Microteaching Model and the control group underwent conventional microteaching learning. The measurement instrument was developed based on Mishra and Koehler's TPACK competency indicators, including TK (Technological Knowledge), TPK (Technological Pedagogical Knowledge), TCK (Technological Content Knowledge), and other integrative aspects. Assessments were conducted before and after treatment to measure competency growth. All data were tested for normality and homogeneity before statistical analysis was conducted, to ensure feasibility of using parametric tests. With this design, it was possible to assess whether the increase in TPACK scores was significant, and whether the model had a different effect compared to the traditional approach.

The results of the statistical analysis showed that the experimental group experienced a significant increase in TPACK scores, from a mean score of 132.91 on the pretest to 165.86 on the posttest, with an increase of 32.95 points. In contrast, the control group only experienced an increase of 9.4 points, from 65.4 to 74.8. The results of the paired sample t-test in the experimental group showed a  $p$  value = 0.000 ( $p < 0.05$ ), which means there is a

significant difference between the scores before and after treatment. Meanwhile, the control group showed a value of  $p = 0.692$  ( $p > 0.05$ ), which means there is no significant difference. The independent sample t-test between groups resulted in a  $p$  value  $< 0.05$ , which confirmed that the model had a statistically different impact on improving TPACK skills compared to the conventional method. This difference is not only statistically significant, but also practically meaningful in developing prospective teachers' professionalism.

To clarify the differences that occurred, the pretest and posttest results were visualized in a bar graph. It can be seen that the experimental group experienced a much higher spike than the control group, confirming that the model is not only able to stimulate the improvement of technological knowledge, but also form an integrative ability in applying pedagogy and content simultaneously through technology. This finding is also supported by observations during the learning process, where students in the experimental group showed more initiative in designing digital media, selecting appropriate interactive platforms, and evaluating the learning process independently. The consistent improvement in all TPACK indicators strengthens the model's position as a systemic and scalable technology-based microteaching training tool. These results support the literature that instructional design-based hybrid learning has a strong effect on teachers' professional skills (22). Further analysis of the TPACK dimensions showed that the Technological Knowledge (TK) component experienced the greatest improvement, followed by TPK (Technological Pedagogical Knowledge) and TCK (Technological Content Knowledge). Students are better able to explain the function and use of various digital tools such as LMS, AR tools, and AI-based automatic evaluation systems. They are also able to link the use of technology with learning strategies and the type of content taught. In post-learning reflection, most students stated that they are more confident in choosing and adapting technology for different teaching contexts. This finding is in line with research (23), who emphasized that synchronous technology and real scenario-based training can increase the complexity of technology-based pedagogical thinking.



Furthermore, these results make a theoretical contribution towards strengthening the TPACK framework, particularly in the context of practice-based training. Whereas previous studies have emphasized the importance of technological literacy in teacher training, these findings emphasize the importance of learning designs that authentically integrate technology in the simulated teaching flow. The synchronous hybrid approach used in this model encourages participants to develop reflective and data-driven instructional decisions, through features such as automatic feedback and evaluative dashboards. Thus, the results of this study not only strengthen the position of TPACK as a conceptual framework, but also present an implementable model that can be implemented in a similar study programme. In addition, the findings open up new areas of study regarding the relationship between digital technology literacy and prospective teachers' reflective skills.

Practically, the effectiveness of this model strengthens the recommendation that LPTK adopt a microteaching learning system that not only emphasizes technical teaching skills, but also the ability to design, manage, and evaluate the learning process with technological support. In the context of the Merdeka Belajar Kampus Merdeka (MBKM) policy, where flexibility, digitalization, and strengthening practice are the three main pillars, this model provides a strategic alternative to strengthen the professional readiness of prospective teachers. The effectiveness of this model proves that technology integration does not have to sacrifice pedagogical aspects, it can enrich the learning experience if designed systematically. Therefore, the results of this study can be used as a reference for developing a teaching practice curriculum in LPTK that is relevant to the demands of the times and the changing needs of the education field.

### **Comparison of Experimental and Control Groups**

Comparison between experimental and control groups is an important part of evaluating the effectiveness of learning models. The aim is to ensure that the increase in TPACK competence that occurs is not the result of chance, but is a direct consequence of the application of the Hybrid Microteaching Model. In this study, the analysis was conducted through a comparison of pretest

and posttest scores from each group, as well as through a test of differences between groups using an independent sample t-test. The test results showed a significant difference in score improvement between the two groups. The experimental group experienced an increase of 32.95 points, while the control group only experienced an increase of 9.4 points. This large difference indicates that the treatment applied to the experimental group produced a stronger learning impact than the conventional method. With this approach, quantitative analysis serves not only for statistical verification, but also as the basis for pedagogical arguments on the effectiveness of model innovations.

The independent sample t-test resulted in a value of  $t = 5.21$  and  $p = 0.000$  ( $p < 0.05$ ), which means there is a significant difference between the posttest results of the experimental and control groups. The effect size value was also calculated using Cohen's  $d$  formula to assess the strength of the impact of the developed model. The calculation results show that the value of Cohen's  $d = 1.36$ , which falls into the large effect category. This indicates that the effect of the model is not only statistically significant, but also pedagogically substantial. The use of effect size is very important in educational research because it allows practical interpretation of statistical data, i.e. how much influence the model has on changes in learners' abilities. In this context, the results show that the Hybrid Microteaching Model is able to provide a much more meaningful increase in TPACK competence than the traditional method.

Furthermore, descriptive analysis showed that the experimental group showed an even improvement in almost all TPACK indicators, while the control group showed limited improvement only in the Pedagogical Knowledge (PK) aspect. This can be explained because conventional approaches tend to emphasize methodological aspects manually, without deep integration of technological systems. In contrast, the model tested in the experimental group integrated various technology platforms such as LMS, AI-based feedback, and AR-based simulation, which provided a more authentic and complex learning experience. The implication of this data is that a learning design that not only adds content, but also shapes a reflective digital learning environment, is able to produce a higher impact on

prospective teachers' ability to manage technology-based learning.

This comparison also strengthens the argument that technology readiness without a strong instructional design is not effective enough in improving prospective teachers' teaching competencies. The control group, which only received a conventional teaching simulation with a simple lecture and practice approach, did not show any significant development in the technological aspect. In other words, the provision of tools alone does not guarantee the improvement of technological competence; there needs to be a learning model that encourages dynamic interaction between students, materials, and learning technology. The Hybrid Microteaching Model developed in this research answers this challenge by structuring learning steps that actively involve students through the digital ecosystem. This distinguishes this model from the usual blended model, because its syntax is explicitly designed to shape technological skills, not just transferring content to the online realm.

From an institutional perspective, this finding implies that LPTK needs to redefine the design of the microteaching curriculum. The teaching practice curriculum should no longer be designed only to train basic skills such as opening lessons or delivering material. In the context of the 21st century, teacher competence is determined by their ability to integrate technology, understand the characteristics of digital learners, and create adaptive and collaborative learning. Therefore, the data showing significant differences between the two groups is not only relevant for model development, but also for policymakers and educational institutions that want to update the teacher training system. These results strengthen the position of the Hybrid Microteaching Model as a strategic alternative in technology-enabled teacher education.

Overall, the comparison between the experimental and control groups provide strong empirical evidence that the synchronous hybrid approach in microteaching has significant advantages in building TPACK competencies. Not only is there a statistical increase in scores, but also a transformation in the way students think in designing lessons. These advantages not only have an impact on academic performance, but also on

their readiness to face the dynamics of real classrooms that are increasingly digitized. Thus, this model is worth recommending as an integral part of the microteaching practice curriculum reform in LPTK, in response to the disruption of digital education and the demands of Merdeka Belajar that emphasize flexibility, innovation, and context relevance.

### **Integrative Discussion**

The results of this study indicate that the Hybrid Microteaching Model significantly improves the TPACK competencies of prospective teachers. This improvement does not only occur in the technical dimension (TK), but also in integrative dimensions such as TPK and TCK. This finding strengthens the validity of the Technological Pedagogical Content Knowledge (TPACK) theoretical framework developed Mishra and Koehler, which asserts that effective teaching competence in the digital era requires a balanced integration of the three knowledge domains (3). In this context, the model developed does not only teach technology as a tool, but positions it as an epistemological element that integrates with pedagogical strategies and the content being taught. The reinforcement of TPACK through a structured hybrid practice approach strengthens the claim that this framework is not merely conceptual, but can be implemented in reality through proper instructional design. In other words, this model serves as a concrete form of implementing TPACK theory in the realm of teacher education.

When compared with previous studies, the findings of this research show both continuity and extension. For example, a study found that the use of digital simulations in microteaching can improve students' confidence and pedagogical skills. However, their approach was still limited to the use of videos and one-way online platforms (24). Previous research underlines the importance of using technology to build interactive communication, but has not specifically examined its contribution to the full TPACK component. Previous research also showed that supervision technology can improve the effectiveness of academic feedback, but it was not explicitly designed in the context of microteaching training (25). The model developed in this study integrates all these aspects simultaneously and comprehensively, with a syntax that allows for in-depth interaction, reflection and assessment. This

provides a new empirical contribution to the literature on the development of digital-based microteaching models.

The main novelty of this research lies in the hybrid synchronous approach equipped with real-time technologies such as Artificial Intelligence (AI) for automatic feedback, and Augmented Reality (AR) for immersive classroom simulation. This integration allows students to not only practice delivering the material, but also evaluate and revise their practice based on instant data and feedback. This approach has not been found in previous literature, which tends to separate practice, reflection, and assessment sessions. This model brings all three together in one flexible and continuous learning system. The innovative use of AR through platforms like Assemblr Edu, for example, expands students' pedagogical imagination by creating a more realistic and participatory learning environment (26). In addition, the use of AI to assess liveliness, intonation, and presentation structure opens up a space for objective reflection that was previously difficult to do manually. Thus, this model bridges the gap between TPACK theory and scalable digital learning practices.

Another scientific contribution is the reinforcement of the concept of reflective and adaptive learning in teacher education. In this model, reflection does not only occur subjectively through personal notes, but also based on performance data generated in real-time by the system. Students can access the history of their teaching activities, review recordings, and analyze strengths and weaknesses based on predetermined indicators. Thus, the reflection process becomes richer and more structured, in accordance with the principles proposed by Schön on reflective practice. The adaptability of the model is also reflected in the flexibility of time and place, as well as the ability to adjust tools and platforms to the needs of students. With these characters, the Hybrid Microteaching Model not only develops techno pedagogical skills, but also trains students' reflection power and adaptive capacity as prospective professional teachers.

This discussion also has a strategic impact on the development of teacher training systems in LPTK. In the context of technological disruption and MBKM policies that demand flexibility and innovation, this model offers solutions that are not

only theory-based, but also empirically tested. The effectiveness and practicality of the model prove that a TPACK-based learning approach can be implemented through careful techno pedagogical design. This answers the challenge that TPACK is difficult to implement due to the complexity of its integration. By presenting a learning model that is modular, structured and supported by the latest technology, this research makes an applicable contribution to teacher education reform.

Considering all the results and their relationship with theories and previous studies, it can be concluded that the synchronous-based Hybrid Microteaching Model is a practice learning model that is not only valid and practical, but also theoretically and empirically effective. This approach combines aspects of modern instructional design with concrete field needs, resulting in a microteaching training system that is responsive to technological developments and the dynamics of higher education. By contributing to the development of TPACK, reflective learning, and technological innovation, this model deserves to be a reference in the development of future teacher training systems. Its main advantage lies in its ability to integrate the complexity of TPACK in a simple, applicable and institutionally relevant framework.

### **Practical and Theoretical Implications**

The findings of this study produce practical implications that are relevant to the Educational Personnel Education Institution (LPTK), especially in the context of developing a technology-based teacher training system. The Hybrid Microteaching Model developed proved to be not only valid and practical, but also effective in improving the TPACK competencies of prospective teachers. Therefore, this model is recommended to be implemented more widely in LPTK that have minimum digital infrastructure and commitment to innovative learning. The implementation of this model can be initiated through integration into microteaching practice courses or peer teaching training, utilizing the institution's Learning Management System (LMS) as the main coordinating medium. The availability of online platforms and automated evaluation tools such as AI-feedback systems make this model relatively easy to adopt with minor adaptations according to the context of each institution (27). With this step, LPTK can strengthen the teacher training ecosystem that is

not only oriented towards content mastery, but also digital skills and reflective abilities.

Another practical implication is the need to adjust and strengthen the microteaching practice curriculum in teacher training programs. The curriculum that has been focusing on conventional observation and simulation needs to be redesigned by incorporating elements of learning technology, utilization of performance data, and reflection based on digital instruments. The results show that the synchronous hybrid approach can accommodate these needs by providing a complete learning flow, from planning, implementation, assessment, to reflection. This model also allows instructional differentiation, where students with different technical abilities can adjust their learning rhythm. Strengthening the curriculum does not mean eliminating offline practice entirely, but integrating online experiences in a balanced and systematic way. Thus, this approach supports the strengthening of 21st century competencies as proclaimed in the Indonesian National Qualifications Framework (KKNI) and professional teacher education standards (28).

From an institutional perspective, the results of this study suggest the need to strengthen teaching laboratory facilities that support hybrid learning. Microteaching laboratories that have been functioning as offline simulation rooms need to be equipped with digital devices such as cameras, interactive screens, streaming systems, and editing rooms. In addition, institutions need to provide a stable and user-friendly LMS platform, as well as regular training for lecturers to maximize the function of the technology. The availability of this infrastructure will expand students' opportunities for flexible, reflective and well-documented teaching practice. This is in line with the recommendations penelitian terdahulu who emphasize the importance of infrastructure and training as key factors in the successful implementation of blended and hybrid learning models. With strong institutional support, the implementation of the model will not only be a local experiment, but part of the systemic transformation of teacher education in Indonesia (29).

Theoretically, the results of this study strengthen the external validity of the TPACK framework, while making an empirical contribution to technology-based instructional design. The model

developed shows that technology integration in practical learning is not an optional extra, but an essential need in the face of digital education disruption. The hybrid synchronous approach with AI and AR support allows the TPACK framework to become not only a theoretical abstraction, but also an applicable framework that can be applied in various teacher training contexts. This adds to the evidence that technology can be used not just as an assistive medium, but as a pedagogical agent that drives change in the way teachers learn and teach (30). This research also highlights the importance of a learning system design approach that is based on the needs and characteristics of the current generation of digital learners.

Another theoretical implication relates to expanding the understanding of technology-based reflective learning processes. The model shows that reflection can be built not only through subjective instruments such as journals or portfolios, but also through digital data such as activity logs, automated scores and video analysis. This marks a shift from traditional reflection approaches to data-driven reflection, which is more objective and traceable. This approach makes a new contribution to reflective learning theory as developed by Schön and Brookfield, by combining the principles of critical reflection and technology-based learning. Students are not only asked to analyze their practice narratively, but also to examine the digital evidence generated from their practice. Consequently, the learning process becomes more in-depth and purposeful.

Finally, this study contributes to the discourse of adaptive learning in teacher education. The model developed demonstrates that digital learning systems can support instructional differentiation and high adaptivity to student needs. By incorporating features such as modular LMS, flexible synchronous sessions, and automated assessments, the model is able to respond to variations in learning styles, technology readiness, and student interaction preferences. This concept supports recent literature in adaptive learning which states that effective learning should be designed to adapt to individual and group dynamics (31). Theoretically, the findings of this study not only strengthen the TPACK framework, but also extend it in important ways. The integration of AI-based feedback and AR simulations shows that reflective practice can

move beyond narrative reflection to data-driven reflection, where teachers analyse automated performance indicators alongside their subjective insights. This extends the traditional understanding of TPACK by highlighting the role of technology as a pedagogical tool and evaluative agent. Moreover, the results suggest that the synchronous hybrid model can be a new pathway for operationalizing TPACK in teacher training, challenging the assumption that technology integration is only additive. Instead, technology becomes an epistemological element embedded in the teaching and learning process. This theoretical contribution strengthens the position of TPACK as a dynamic framework that can evolve in response to advances in educational technology.

## Conclusion

The findings of this study confirm that the Hybrid Microteaching Model significantly contributes to the improvement of prospective teachers' TPACK competencies through the integration of LMS-based synchronous technology, artificial intelligence (AI), and augmented reality (AR). The high design validity, practicality of implementation, and empirical effectiveness in improving key dimensions of TPACK indicate that this model is not just a methodological innovation, but a strategic solution for teacher training in the digital era. By strengthening reflective, adaptive and data-driven learning, the model addresses the challenges of transforming teacher education and fills the gap between TPACK theory and field practice. Therefore, the adoption of this model in LPTK and the expansion of its use across disciplines are recommended as concrete steps in building a more relevant, transformative, and future-oriented teacher training ecosystem.

## Abbreviations

AI: Artificial Intelligence, AR: Augmented Reality, CK: Content Knowledge, KKNI: Kerangka Kualifikasi Nasional Indonesia, LKPD: Lembar Kerja Peserta Didik, LMS: Learning Management System, LPTK: Lembaga Pendidikan Tenaga Kependidikan, MBKM: Merdeka Belajar Kampus Merdeka, PCK: Pedagogical Content Knowledge, PK: Pedagogical Knowledge, R and D: Research and Development, TCK: Technological Content Knowledge, TK: Technological Knowledge, TPACK: Technological Pedagogical Content Knowledge, TPK: Technological Pedagogical Knowledge.

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## Author Contributions

Mochamad Nashrullah: Conducted research, analysed data, wrote the original draft of the script, Suryanti: Supervised the overall research, provided guidance on methodology, conducted final review and editing of the manuscript, Nunuk Hariyati: Supervised the overall research, provided guidance on methodology, conducted final review and editing of the manuscript, Gunarti Dwi Lestari: Supervised the overall research, provided guidance on methodology, conducted final review and editing of the manuscript.

## Conflict of Interest

There is no conflict of interest associated with this study. This research is original and independent, not a part of any other studies.

## Declaration of Artificial Intelligence (AI) Assistance

The authors declare no use of artificial Intelligence (AI) for the write up of the manuscript.

## Ethics Approval

Not Applicable.

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