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Transforming Reflective Learning in Teacher Education: The Role of Metacognitive Dynamics in Adaptive Gamified Systems

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ABSTRACT

Developing reflective competence in pre-service teachers is essential for fostering critical and adaptive thinking, yet conventional methods often fall short in promoting deep metacognitive awareness. This quantitative study employed a quasi-experimental design involving 120 education students from two Indonesian universities, divided into experimental and control groups. Data were gathered through pre- and post-tests, observations, and perception questionnaires, and analyzed using ANCOVA. Findings revealed that integrating metacognitive elements into adaptive gamification significantly enhanced students' reflective competence compared to traditional methods. The results suggest that gamification tailored to metacognitive levels can effectively stimulate meaningful reflection. This study contributes to the theory of adaptive, technology-based learning models and offers practical insights for improving reflection-focused teacher education curricula.

INTRODUCTION

In the era of globalization and digital disruption, prospective teachers are required to have high reflective competence in order to be able to think critically and adaptively in dealing with the complexity of learning in the 21st century (Caena & Redecker, 2019). Metacognition, the ability to "think about thinking", has been shown to play an important role in forming reflective attitudes and better decision-making (Rivas et al., 2022). However, research in Indonesia shows that traditional learning methods are still less effective in stimulating the metacognitive awareness of prospective teachers, which has the potential to reduce the quality of teaching in the future. Meanwhile, globally, adaptive gamification is beginning to be adopted in various formats of higher education as an innovative approach to increase motivation and self-awareness through the adjustment of learning strategies according to the player model (Costello, 2020).

Although adaptive gamification is gaining popularity, most studies still focus on the motivational and self-regulation aspects (Li et al., 2022), without exploring its metacognitive implications in depth. (Wang et al., 2021) Found that the integration of challenges and scaffolding can improve students' metacognitive awareness in the context of educational play, but the effect has not been tested on prospective teachers. Additionally, a study by (Villarroel et al., 2024) highlights the lack of gamification design that explicitly supports metacognitive reflection during the process, rather than just after learning. Thus, there is still a research gap related to how adaptive gamification equipped with metacognitive elements can systematically build the reflective competence of prospective pre-service teachers in Indonesia.

This study aims to empirically examine how the integration of metacognitive components such as planning, monitoring, and self-evaluation in adaptive gamification design can improve the reflective competence of prospective pre-service teachers. Explicitly, this study was designed using a quasi-experimental design with 120 students from two universities in Indonesia, divided into experimental and control groups. Data were collected through pre-test and post-test, observation, and perception questionnaires, then analyzed with ANCOVA to measure the effect of treatment (adaptive gamification group) on the improvement of reflective competence compared to traditional approaches.

Theoretically, this study complements the educational gamification literature by adding an explicit adaptive model of metacognition, expanding the understanding of gamification design from just the motivational aspect to the realm of critical reflection (Hao & Tasir, 2024). Practically, the results of this study offer a technology-based adaptive learning design model that can be integrated into the teacher's education curriculum, improving the quality of reflection of prospective teachers in the preparation of professional practice. Thus, this research not only enriches instructional design theory, but also presents direct implications for teacher higher education practices in Indonesia and global contextual.

The context of teacher education in Indonesia faces a major challenge in forming educators who not only master the content, but also have reflective

maturity in carrying out learning practices. A report by the Ministry of Education, Culture, Research, and Technology shows that most prospective teachers have difficulty in reflecting deeply on their teaching experience, which has an impact on the low quality of instructional planning and adjustment. This condition is exacerbated by a learning approach that is still one-way and less interactive. With the increasing use of technology in education, there is an opportunity to intervene in the learning process of prospective teachers through a technology-based approach that is not only visually appealing, but also supports the development of self-awareness and critical reflection in a systematic manner (Loeneto et al., 2022).

Metacognition includes the ability to plan, monitor, and evaluate one's own thought processes (Rivas et al., 2022), and when integrated in the context of gamification-based learning, it can be an important foundation in forming a sustainable reflective attitude. Adaptive gamification has greater potential than conventional gamification because it is able to adapt the dynamics of the game to the needs and cognitive abilities of students (Zourmpakis et al., 2023). These adjustments not only encourage engagement, but also open up space for participants to reflect on their learning strategies. A study by (Subramanian, 2022) shows that elements such as self-feedback, challenge calibration, and real-time goal reflection in gamification play a major role in increasing students' metacognitive awareness. Therefore, the use of this approach in teacher education can bridge the gap between learning theory and reflective practice in the field.

LITERATURE REVIEW

The development of 21st century education requires prospective teachers to not only master the learning content, but also to have strong reflective skills to deal with the complexity of teaching practices in dynamic classrooms. Reflective competencies allow teachers to analyze experiences, evaluate practices, and make continuous improvements to the learning strategies used (Pang, 2022). Various studies show that reflection does not arise naturally, but needs to be cultivated through consciously and systematically designed learning experiences, especially by involving metacognitive processes (Silver et al., 2023). In the context of higher education in Indonesia, learning is still dominated by conventional approaches that are less able to stimulate the reflective awareness of prospective teacher students, so an innovative technology-based approach that is more adaptive to the learning characteristics of the current digital generation is needed (Cahyadi et al., 2021).

Gamification has become one of the popular pedagogical approaches that incorporate elements of games to improve learners' motivation, engagement, and learning outcomes (Mee et al., 2021). However, most gamification research in education is still focused on motivational and behavioral aspects, while the cognitive and metacognitive dimensions are often overlooked (Slamet, 2024). (Zainuddin et al., 2024) Emphasized the importance of developing gamification based on reflective learning, but there are not many models that explicitly integrate metacognitive strategies such as planning, monitoring, and self-

evaluation in educational game design. A study by (Lampropoulos et al., 2022)shows that when these elements are integrated into adaptive gamification systems, there is a significant increase in students' reflective awareness and self-learning, although the context is not yet specific to teacher education.

Meanwhile, in their critical review, (Ibisu, 2024) developed an adaptive gamification taxonomy that tailors the learning flow to the participants' preferences, abilities, and developmental levels. Although this model offers a flexible framework to support personalized learning, its integration in teacher education is still minimally explored, especially in building reflective competencies as key learning outcomes. (Chen & Hou, 2025) research also states that reflective tasks incorporated in gamification learning flows can facilitate metacognitive internalization, but the approach used has not taken into account the cultural and social context of students in developing countries such as Indonesia. Therefore, it is important to develop metacognition-based adaptive gamification designs that are contextual and relevant to the educational characteristics of local teachers.

From a methodological perspective, the quasi-experimental approach is a widely used method in technology-based learning design studies to test the effectiveness of treatment of learning outcome variables (Mulyadi et al., 2021). The validity of reflective competency measurement instruments is generally developed from metacognitive awareness inventory scales (Aldea, 2024) that have been extensively modified according to modern learning contexts, including the integration of gamification and digital technologies (Amriza et al., 2024). The use of advanced statistical analysis such as ANCOVA is becoming common practice to control for initial variables and isolate the effects of interventions on experimental and control groups. To support data analysis, software such as SPSS and AMOS are often used in technology-based educational research due to their ability to manage complex quantitative data and test relationships between variables simultaneously.

Taking into account previous studies, this study offers an integrative approach that incorporates metacognition principles in adaptive gamification design to strengthen the reflective competence of prospective teacher students. This integration is expected to answer the gap in the existing literature, namely the lack of technology-based learning models that directly target the development of reflective awareness of prospective teachers in the context of pre-service education. More than that, the results of this research have the potential to make a significant contribution to the development of teacher education curriculum in the digital era, by providing data-based and reflection-based instructional models that are contextual, applicative, and sustainable.

METHODOLOGY

Types and Approaches to Research

This study uses a quantitative approach with a quasi-experimental design. This design was chosen because it allows testing the effects of metacognition-based adaptive gamification interventions on two groups experimental and control with pre-test and post-test measurements before and after treatment. This

approach is commonly used in education, technology, and gamification research (Abadi et al., 2025).

Population and Sampling Techniques

The research population is all students of pre-service education study programs at two universities in Indonesia in the 2024/2025 academic year. The sampling technique used purposive sampling (non-probability), because the researcher selected participants who met the criteria: taking an Innovative Education course and actively participating in the gamification platform. The total sample consisted of 120 students, divided equally into experimental (n=60) and control (n=60) groups. This number meets the minimum size recommendations for ANCOVA analysis (Shieh, 2020).

Instruments and Validity–Reliability

Data collection was carried out through:

a. Reflective competency pre-test and post-test
b. Observation of activities on gamification platforms
c. Questionnaires of participants' perceptions of learning experiences.

The test instrument was developed by adapting the inventory of metacognitive awareness (Tak et al., 2022). The perception questionnaire was compiled based on the GAFCC model (Huang et al., 2019). The validity of the content was tested through review by three experts in education, technology, and metacognition. Reliability was tested using Cronbach's alpha method in the pilot study (n=30), with a value of $\alpha > .70$ as the accepted quality limit.

Implementation Procedure

The research procedure includes the following stages:

a. Submission of Ethical Review permits and informed consent from participants.
b. Implementation of pre-test tests and filling out initial questionnaires.
c. An eight-week intervention of the experimental group followed adaptive gamification-based learning that presented elements of planning, monitoring, and self-evaluation; while the control group followed conventional learning.
d. Observation of participant activities in each session using checklist instruments.
e. Post-test and collection of perception questionnaires.
f. Debriefing and termination of interventions. All measures are carried out in parallel at the two universities to reinforce generalizations.

Data Analysis Techniques and Tools

Data analysis was conducted using the ANCOVA technique to test the effect of adaptive gamification interventions on the improvement of reflective competence. The pre-test variable is included as a covariate to minimize initial bias. Perception data were analyzed descriptively and inferentially with a t-test

on the average score. Observational analysis was carried out using the frequency and pattern of presence of metacognitive elements. All analyses use IBM SPSS Statistics software version 26.0.

RESEARCH RESULTS

This study aims to analyze the effect of metacognition integration in adaptive gamification design on improving the reflective competence of pre-service teacher education students. Data were obtained through pre-test and post-test reflective competency, learning observation, and perception questionnaires from 120 students who were divided into experimental (n=60) and control (n=60) groups. Here is a summary of the results of the average pre-test and post-test scores:

Table 1. Reflective Competency Pre-test and Post-test Average Scores

Group	Pre-test (Mean)	Post-test (Mean)	Score Improvement
Eksperimen	62.5	84.2	21.7
Control	63.1	70.3	7.2

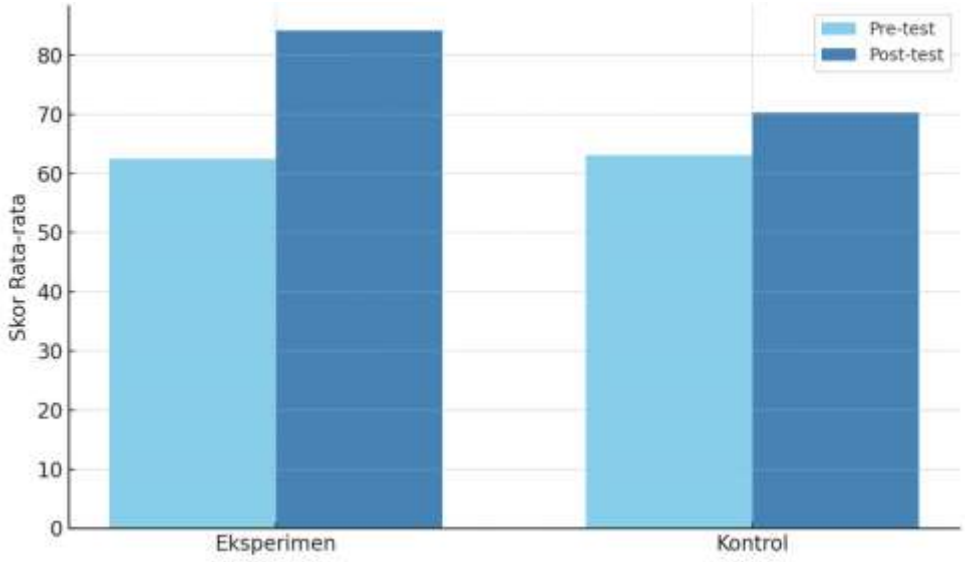

Figure 1. Reflective Competency Pre-test and Post-test Comparison

The results of the ANCOVA test showed that there was a significant difference between the experimental and control groups in the improvement of reflective competence after treatment ($F(1,117) = 28.47$, $p < 0.001$). The experimental group that received the metacognition-based adaptive gamification treatment showed a score increase of 21.7 points, while the control group that used conventional methods only increased by 7.2 points.

In addition, the results of the observations showed that students in the experimental group were more active in conducting independent and

collaborative reflection, as seen from their involvement in activities such as process evaluation, replanning learning strategies, and asking reflective questions during the session.

DISCUSSION

The results of this study reinforce previous findings that the integration of metacognitive elements in an adaptive learning environment is able to significantly improve students' reflective competence (Antonio, 2020). Improved scores in the experimental group showed that learning strategies that emphasized metacognition cycles planning, monitoring, and evaluation facilitated the formation of stronger reflective awareness. This is in line with the view of Schraw and Dennison (1994) who stated that involvement in metacognitive strategies can increase the effectiveness of long-term learning (Schraw & Gutierrez, 2014).

A considerable improvement in the experimental group (21.7 points) compared to the control group (7.2 points) demonstrated the apparent effectiveness of the adaptive gamification approach in the context of teacher education. Elements such as graded challenges, instant feedback, and mission-based reflection not only increase engagement but also help participants understand their thought processes. This approach answers criticism of traditional gamification that tends to be only oriented towards external rewards (Hung, 2017), by directing it to more meaningful learning.

The difference with previous research that only emphasized motivation or cognitive achievement without including metacognitive aspects, as found by (Zainudin & Zulkiply, 2023), shows the importance of designing gamification that explicitly targets reflection. These results support the importance of using gamification as an instrument not only to generate enthusiasm for learning, but also to form critical and sustainable reflective thinking.

Supporting factors for the success of this study include gamification design that is adaptive to the participant's level of development, the use of interactive platforms, and metacognitive scaffolding through digital reflective guidance. However, there are limitations in the relatively short implementation period (8 weeks), as well as dependence on digital instruments that require participants' technological literacy. In addition, students' perceived responses to gamification also vary, mainly influenced by learning preferences and previous experiences.

Another limitation is that no follow-up measurement has been carried out to see the durability of the reflective competencies that have been formed. For this reason, advanced research is recommended to adopt a longitudinal approach and extend the intervention to the context of field practice (PPL) so that students' reflections are not only theoretically awakened, but also applicative. Overall, these findings make an important contribution to the field of instructional design, particularly the development of adaptive learning models that combine metacognition and gamification. Its practical contribution can be applied in the teacher education curriculum to improve the quality of reflection of prospective teachers in facing professional challenges in the future.

CONCLUSIONS AND RECOMMENDATION

This study successfully examined the effect of metacognition integration in adaptive gamification design on improving the reflective competence of pre-service teacher education students. Through a quasi-experimental approach, the results of the analysis showed that the group that received metacognition-based adaptive gamification treatment experienced a significant increase in reflective competency score of 21.7 points, compared to the control group which only increased by 7.2 points. This shows that the development of metacognition-based learning strategies that are designed adaptively can stimulate reflective awareness and student learning engagement more optimally.

The improvement is supported by learning activities that encourage a process of planning, monitoring, and self-evaluation that is integrated into the educational game mechanism. The results of observations and perception questionnaires also showed that students in the experimental group showed a more active tendency to reflect on their learning process, both individually and collaboratively. These differences in results confirm the importance of preparing a gamification design that is not only oriented towards motivational incentives, but also pays attention to the metacognitive dynamics of learners contextually.

The integrative approach between adaptive instructional design and metacognitive strategies has proven to be effective in improving the reflective competence of prospective teachers, as well as making a real contribution to the development of technology-based learning models in higher education. These findings can be a reference for curriculum developers and education practitioners in designing learning that is able to prepare prospective teachers to be reflective, critical, and adaptive to change. Further research is recommended to be carried out longitudinally and applied in the context of field practice so that the validity of the model is stronger and more applicable in the world of the teaching profession.

FURTHER STUDY

Building on these findings, further research is recommended to conduct longitudinal studies that examine the long-term impact of metacognition-based adaptive gamification on reflective competence throughout the teacher education process. Future studies should also explore the application of this model in real classroom settings during teaching internships or field practice to assess its practical effectiveness and scalability. Additionally, comparative studies across different educational levels and disciplines could help determine the broader applicability of this approach. Investigating the role of individual learner characteristics, such as learning styles or digital literacy, may also provide deeper insights into how adaptive gamification can be personalized to maximize reflective learning outcomes.

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