Assessment of Competence of Pre-service Mathematics and Science Teachers in Classifying Cognitive Processes and Knowledge Dimensions through the Revised Bloom's Taxonomy

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Abstract

Effective assessment plays a critical role in fostering students' cognitive development and academic achievement. To achieve this, pre-service mathematics and science teachers must demonstrate competencies in classifying cognitive processes and knowledge dimensions through the Revised Bloom's Taxonomy (RBT). This study investigated the competencies of 156 pre-service teachers from mathematics, biology, physics, and chemistry education programs at a public university in Indonesia in classifying test items according to RBT. Employing a quantitative descriptive design, participants were evaluated on their ability to accurately identify both cognitive levels (C1–C6) and knowledge dimensions (factual, conceptual, procedural, and metacognitive). The results revealed strong proficiency in analyzing (C4), but notable weaknesses in applying (C3) and creating (C6)—two domains essential for developing higher-order thinking skills (HOTS). Moreover, no statistically significant differences were found between male and female participants. These findings underscore the need for strengthening teacher education curricula by integrating targeted training on RBT-based assessment design. Equipping pre-service teachers with such competencies is vital for enhancing students' critical thinking and problem-solving abilities.

Keywords: Revised Bloom's Taxonomy, Mathematics and Science Education, Assessment Literacy, Pre-service mathematics and Science Teachers, Higher-Order Thinking Skills

INTRODUCTION

In order to improve student learning outcomes, inform instructional decisions, and develop higher-order thinking skills (HOTS), assessment is essential. Assessments in science and math classes are used to foster cognitive growth in addition to measuring knowledge. Teachers can better align test items with intended abilities by using the two-dimensional framework provided by the Revised Bloom's Taxonomy (RBT), which consists of cognitive processes (C1–C6) and knowledge domains (factual, conceptual, procedual, and metacognitive). Pre-service instructors are expected to use this framework to create relevant and valid assessments that encourage students to think critically and creatively.

Despite the wide adoption of RBT, several studies indicate that teacher-generated test items still emphasize lower-order thinking skills, with limited application and creation (Mutakin & Hakim, 2021; Avdiaj, 2024). Previous studies also reveal that questioning and assessment practices often neglect meta-cognitive dimensions, thereby limiting opportunities

for cultivating critical thinking (Critelli & Tritapoe, 2010; Bibi, 2020; Rustaman et al., 2019; Demirbas & Demir, 2023). Scholars further emphasize the importance of HOTS-oriented assessment in teacher education (Suwono & Kadarwati, 2021) and its close link to critical thinking development (Fahim & Masouleh, 2020). However, relatively few studies have examined pre-service teachers' competence in classifying test items within the RBT framework, particularly in the Indonesian mathematics and science education context. To address this gap, the present study investigates the ability of pre-service teachers from mathematics, biology, physics, and chemistry programs to classify test items according to RBT and explores potential gender differences, aiming to provide evidence-based insights for strengthening assessment literacy in teacher education.

METHOD

This study adopted a quantitative descriptive design to evaluate the competencies of pre-service mathematics and science teachers in classifying cognitive processes and knowledge dimensions based on the Revised Bloom's Taxonomy (RBT). The design focused on assessing participants' ability to accurately categorize test items within the RBT framework.

Participants

A total of 156 pre-service teachers participated in this study. They were enrolled in four Mathematics and Science-related education programs—mathematics (n = 39), physics (n = 29), chemistry (n = 29), and biology (n = 59)—at a public university in Indonesia. Participants were selected using a purposive sampling technique, with the inclusion criterion being completion of a course in educational assessment. The distribution of participants is presented in Table 1.

Table 1. Distribution of Pre-Service Mathematics and Science Teachers Participants

Program	Number of Participants
Mathematics	39
Physics	29
Chemistry	29
Biology	59
Total	156

Instrumentation

The primary research instrument was a test consisting of seven multiple-choice items. Each item required participants to classify both the cognitive process level (C1–C6) and the knowledge dimension (factual, conceptual, procedural, metacognitive) according to RBT. Correct classification of both dimensions was awarded one point, yielding a maximum possible score of 14.

To ensure instrument validity, Aiken's (1980; 1985) V was used to evaluate content validity, while an inter-rater reliability coefficient (≥ 0.75) was calculated to confirm scoring consistency. Examples of the test items and their correct classifications are provided in Table 2.

Table 2. Sample Test Items and Their Classification Based on RBT

Test Item	Subject	Indicator	Knowledge Dimension	Cognitive Process
Two lenses are arranged; lens B is moved toward lens A. What happens to the light beam?	Physics	Identifying optical behaviors	Conceptual	C1 (Remember)
A ball is placed 50 cm in front of a plane mirror. What is the distance to its image?	Physics	Calculating image distance	Procedural	C3 (Apply)
A patient is dehydrated. What physiological responses occur based on fluid homeostasis mechanisms?	Biology	Applying knowledge of ADH and RAS	Procedural	C3 (Apply)
In an isobaric process, what happens to enthalpy and internal energy if work is done by the system?	Chemistry	Interpreting thermodynamic changes	Conceptual	C4 (Analyze)
Perform matrix multiplication and define group properties.	Mathematics	Defining algebraic properties	Procedural	C3 (Apply)

Data Collection and Analysis

Data were collected through structured tests administered under standardized conditions. The responses were analyzed using descriptive statistics to determine accuracy in classifying cognitive processes and knowledge dimensions. Furthermore, an independent samples t-test was performed to examine potential differences in classification competencies between male and female participants.

RESULTS AND DISCUSSION

Assessment in education must target both lower-order and higher-order thinking skills (LOTS and HOTS). In the Revised Bloom's Taxonomy (RBT), remembering, understanding, and applying fall under LOTS, while analyzing, evaluating, and creating represent HOTS.

Competency in Cognitive Process Classification

The findings in Figure 1 reveal that pre-service mathematics and science teacherss achieved the highest accuracy in classifying items at the analyzing (C4) and remembering (C1) levels. By contrast, they struggled with applying (C3) and creating (C6), which are critical for fostering higher-order thinking skills (HOTS).

These results are consistent with earlier studies showing that pre-service teachers often remain at the analytical stage and rarely design or recognize test items that address application and creation (Mutakin & Hakim, 2021; Rahmatih, 2021). Similarly, Avdiaj (2024) reported that only a small proportion of teacher-generated questions targeted the creation level, while most were limited to recall and comprehension. Such findings confirm that the competencies of pre-service teachers in promoting HOTS remain limited.

Comparatively, in-service teachers have been shown to perform better in constructing higher-order questions (Bibi, 2020; Chandio et al., 2021), suggesting that pedagogical experience significantly influences assessment literacy. This implies that teacher education curricula should integrate authentic training in HOTS-based assessment design, allowing future teachers to progress beyond analytical classifications.
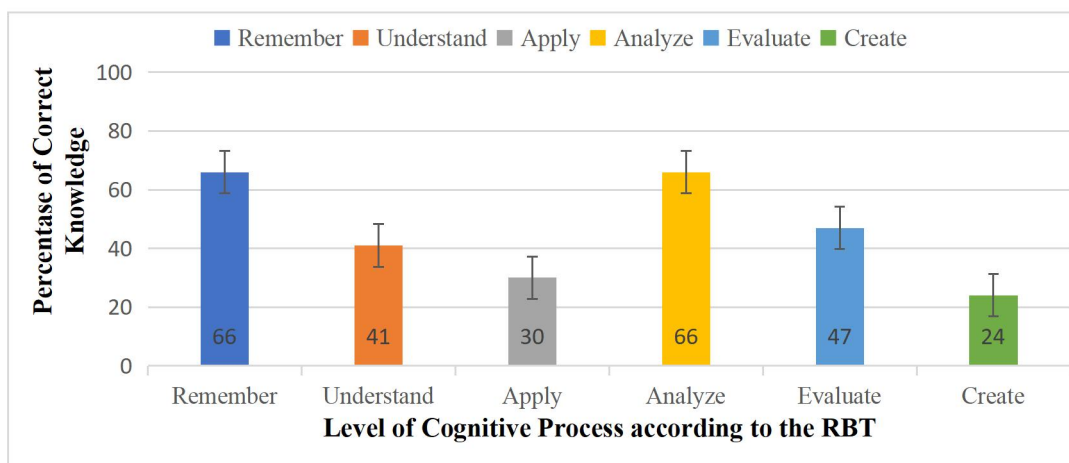

Figure 1. Illustrates the Participants' Performance in Identifying Cognitive Process Dimensions

Competency in Knowledge Dimension Classification

In terms of knowledge dimensions, participants demonstrated strong accuracy in classifying factual and conceptual knowledge (see Figure 2). Moderate performance was observed in procedural knowledge, while metacognitive knowledge was classified least accurately.
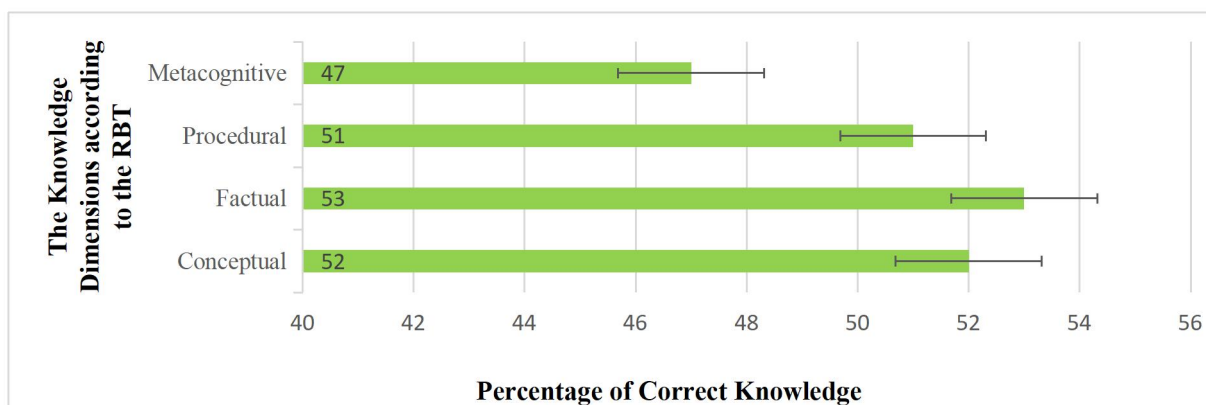

Figure 2. Presents Participants' Accuracy in Identifying the Knowledge Dimension of RBT.

This pattern aligns with previous research showing that both pre- and in-service teachers tend to neglect metacognitive aspects in assessments (Rustaman et al., 2019; Demirbas & Demir, 2023). Metacognition is particularly important because it reflects learners' awareness of their own thinking processes, a skill crucial for lifelong learning (Zhou et al., 2023).

The weak performance in this dimension indicates that pre-service teachers may lack exposure to reflective practices such as self-evaluation, peer feedback, or guided journaling. Integrating these strategies in teacher education programs could enhance their ability to develop assessments that capture higher levels of abstraction and self-regulated learning (Herlanti et al., 2019).

Gender-Based Analysis

The descriptive data in Figure 3 indicated that female participants generally outperformed their male counterparts across remembering, understanding, applying, and evaluating, while both groups showed similar accuracy in analyzing. Both genders performed poorest in creating. In the knowledge dimensions, females excelled in conceptual and meta-cognitive classifications, whereas males performed slightly better in factual knowledge.
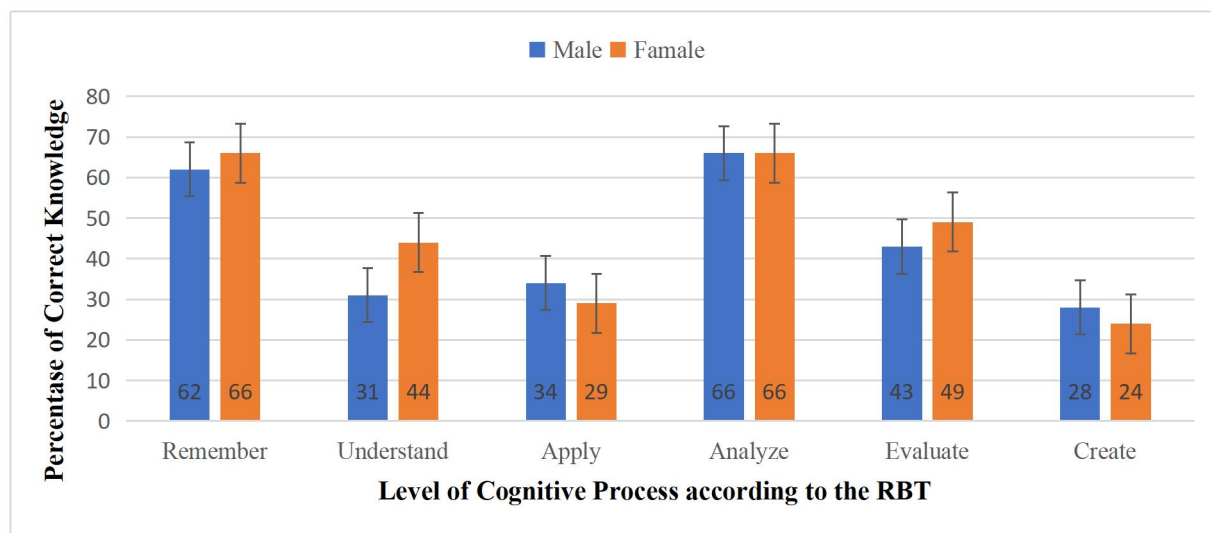

Figure 3. Shows Gender-Based Comparison in Classifying Cognitive Process Levels

Despite these descriptive differences, an independent samples t-test revealed no statistically significant gender effect ($p = 0.806$). This result corroborates previous findings that gender does not substantially influence assessment literacy or item construction competency (Asim et al., 2013; Inko-tariah & Okon, 2019; Barrientos, 2023). Instead, experience, training, and contextual factors play a more decisive role (Chen et al., 2020; Sansone, 2017).

These findings suggest that curriculum interventions should be designed to benefit all teacher candidates, regardless of gender, particularly in improving competencies in application and creation within the RBT framework.

Implications and Recommendations

Overall, the results highlight the urgent need to strengthen assessment literacy in teacher education. Specifically:

- Practical workshops on designing HOTS-oriented items should be prioritized.

- Digital tools and platforms may support accurate RBT classification.

- Reflective practices (e.g., peer review, self-assessment) should be systematically integrated.

By embedding these strategies, teacher education programs can empower pre-service teachers to construct assessments that effectively cultivate students' critical thinking, creativity, and problem-solving—competencies essential in the context of 21st-century STEM education (Long et al., 2014; Luo & Chen, 2024; Setyorini, 2025).

Statistical Test of Gender Differences

To determine whether gender had a significant impact on the pre-service teachers' competency in classifying cognitive processes and knowledge dimensions based on the Revised Bloom's Taxonomy (RBT), an independent samples t-test was performed.

The results of the analysis are presented in Table 3.

Table 3. Independent Samples T-Test Results Based on Gender

Variable	Levene's Test Sig.	t-test for Equality of Means (Sig. 2-tailed)	Mean Difference	95% Confidence Interval
Classification Competency	0.447	**0.806**	-0.153	[-1.567, 1.261]

Note: p > 0.05 indicates no significant difference between groups.

As shown in Table 3, the significance value of the t-test (Sig. 2-tailed = 0.806) exceeds the alpha level of 0.05, indicating that there is no statistically significant difference in classification competency between male and female pre-service teachers. The 95% confidence interval also includes zero, reinforcing the conclusion that gender does not significantly influence their performance in classifying cognitive and knowledge dimensions using RBT.

This finding supports earlier research by Asim et al. (2013), Inko-tariah & Okon (2019), and Barrientos (2023), all of whom found that gender did not significantly affect teachers' test development knowledge or classification skills. Instead, other factors—such as training experience, exposure to RBT-based assessments, and years of teaching practice—play a more decisive role.

Although descriptive data indicated that female participants performed slightly better across several dimensions (see Figures 3), this difference was not statistically meaningful. Therefore, teacher training programs should focus on competency-based development that supports all candidates, regardless of gender, especially in applying and creating HOTS-oriented assessments.

CONCLUSION

This study evaluated the competencies of pre-service mathematics and science teachers in classifying cognitive processes and knowledge dimensions through the Revised Bloom's Taxonomy (RBT). The findings indicate that participants were relatively proficient in analyzing (C4) and remembering (C1) but showed weaknesses in applying (C3) and creating (C6)—two levels essential for fostering higher-order thinking skills (HOTS). Regarding knowledge dimensions, participants performed best in factual and conceptual classifications, while difficulties were observed in addressing metacognitive knowledge, reflecting limited exposure to reflective and abstract assessment tasks.

Although female participants achieved slightly higher scores across several categories, statistical analysis confirmed that gender did not significantly affect performance. This reinforces the idea that assessment literacy is shaped more by training and experience than by demographic factors.

According to the study's findings, teacher education programs should incorporate focused instruction in RBT-based assessment design, with more of an emphasis on creating tasks at the application and creative levels and on methods for fostering metacognitive thinking. To prepare future educators to create tests that foster students' critical thinking, creativity, and problem-solving abilities, it is imperative that these talents be strengthened. Future studies should use intervention-based or longitudinal methods to investigate the long-term effects of systematic training on RBT abilities. Furthermore, broadening the sample to include more institutions and cultural contexts would offer more comprehensive understandings of how pre-service science and math teachers improve their assessment literacy globally.

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