

## Shaping Future Science Educators: Exploring First-Year Pre-Service Teachers' Mastery of PISA-Style Challenges

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### Abstract

This study investigates first-year science pre-service teachers' abilities and perspectives on PISA questions, addressing Indonesia's low PISA rankings and challenges in teacher preparation. A total of 153 first-year students from four programs at Mulawarman University (mathematics, biology, physics, and computer education) participated. Using a mixed-methods approach, quantitative data were collected through validated PISA test instruments, while qualitative insights were drawn from open-ended responses. The results showed no significant differences in PISA scores by gender or study program, but significant differences emerged when comparing first-year students to third-year students and professional teachers, with first-year students scoring lower. Qualitative findings revealed themes such as the cognitive challenges posed by PISA questions, their ability to foster critical thinking, unfamiliarity with the format, and their real-world relevance. Despite difficulties, many participants found the questions engaging and valuable for developing analytical skills. These findings highlight the need to incorporate PISA-style assessments in teacher education programs to enhance higher-order thinking and better prepare pre-service teachers for international standards in education.

Keywords: Assessment, Critical Thinking, Mixed-Methods, PISA, Pre-Service Teachers

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## INTRODUCTION

PISA (Program for International Student Assessment) is an international study that measures the ability of 15-year-old students in three main domains: reading, mathematics, and science. The study is organized every three years by the OECD (Organization for Economic Co-operation and Development). The aim is to evaluate the extent to which students can apply their knowledge and skills in real-life situations, rather than just testing curriculum-based knowledge. PISA also includes optional domains such as financial literacy and collaborative competence (Nugrahanto & Zuchdi, 2019; OECD, 2006). PISA assesses variables related to

students' socio-emotional well-being, expanding its focus not only on academic performance, but also cognitive, psychological, social, physical, and material aspects of students. PISA aims to identify factors that influence well-being and academic outcomes (Govorova et al., 2020). PISA is considered an important tool for evaluating and improving the quality of education at the global level, although there are concerns regarding its direct policy application without regard to the local context (Hopfenbeck et al., 2018).

PISA results show that Indonesia scores very low in reading, math, and science. Indonesia has continued to rank low in PISA since 2000, ranking 65th out of 69 countries in 2015 (Pratiwi, 2019). Indonesia still lags Southeast Asian countries such as Singapore, Malaysia, and Thailand (Argina et al., 2017; Fenanlampir et al., 2019). Sadly, from 2000 to 2018, the trend of Indonesian students' PISA results in reading and math showed a downward trend despite three curriculum changes (Pendidikan et al., 2022). If this is left unchecked, Indonesian students are in danger of not being able to reach the ideal standard of ability to participate as active and constructive citizens in the future. Worse still, they may not be able to compete with communities in other countries (Pendidikan et al., 2022).

One of the main causes is the suboptimal quality of teaching, where many teachers have not received adequate training to meet international standards as set by PISA (Argina et al., 2017; Nandang Mustafa, 2023). Another study also revealed that less than half of teachers in Indonesia have achieved the minimum qualifications to teach (Narmamatovich Shaturaev, 2021) This is also evidenced by a study that analyzed how science teachers and third-year science pre-service teachers dealt with PISA character questions, and found that they were unfamiliar with and had not mastered these questions (Agustiani, 2020). However, there is still no in-depth research that analyzes how first-year science pre-service teachers deal with PISA questions.

The first year of college is a transitional period, a period where a student is still adjusting to changes in both the learning system and the new environment, from the high school environment to the college environment. In this period, a student still shows learning behavior when in senior high school. Most of them do not have the readiness to learn independently as needed in college. Control over learning activities is so lacking that it can result in failure to obtain optimal academic achievement if not immediately anticipated. Students have a lot of free time to study, but they do not use the time properly for learning. They spend more time watching TV, reading magazines or comics, playing games, chatting, or activities that are less useful (Darmiany, 2016). Previous studies also found that 60% of first-year science teacher candidates showed low chemistry laboratory literacy. Of course, this low laboratory literacy can reflect the low literacy skills of first-year pre-service teacher, and is interesting to study (Zuhaida & Imaduddin, 2019). Therefore, analyzing their basic abilities in solving PISA character questions is an important study to provide effective treatment and policies, preparing them during their studies to become professional teachers in the future.

The purpose of this study is to inform policymakers and educators about how to effectively support first-year pre-service teachers, ensuring their mentoring is maximized and that they are properly prepared to become professional educators. Specifically, this research seeks to address several key questions. First, it aims to investigate how gender influences the ability of first-year science pre-service

teachers to answer PISA-style questions. Second, it explores the impact of the study program origin on the performance of these teachers when responding to PISA character questions. Third, the study compares the responses of first-year science pre-service teachers with those of third-year pre-service teachers and professional teachers to identify any significant differences. Lastly, the study examines the perspectives of first-year science pre-service teachers regarding PISA character questions, focusing on their thoughts and challenges related to the assessment.

## RESEARCH METHOD

This study employed a mixed-methods design, integrating both quantitative and qualitative analysis. This design was chosen to provide a comprehensive understanding of first-year science pre-service teachers' abilities to answer questions based on PISA characterizations. The quantitative component, involving validated PISA test instruments in previous study (Agustiani, 2020), allows for statistical comparisons between groups based on gender, study program, and professional experience. The qualitative analysis, which involves free-response questions, helps to capture the participants' perspectives on the PISA questions, providing rich insights into their thought processes. A mixed-methods approach was deemed appropriate as it allows the study to answer both the question of "how" (quantitative) and "why" (qualitative) regarding first-year science pre-service teachers' abilities and perspectives.

The participants in this study were 153 first-year science pre-service teachers from Mulawarman University in Indonesia, selected from four study programs: mathematics education (54), biology education (25), physics education (13), and computer education (61). This diverse sample was purposefully selected to ensure response variability based on academic background. The first-year students were chosen as they are in the early stages of their teacher preparation, and their performance on PISA-based questions could provide valuable insights into their readiness and competence. Data collection consisted of two phases: a 60-minute test using PISA test instruments, and a qualitative component where participants responded to free-response questions about their experiences with the PISA tasks.

For data analysis, the PISA test results were examined first using statistical tests. The Kolmogorov-Smirnov test was applied to check for the normality of the data. To examine the effect of gender on PISA test performance, an independent-samples t-test was conducted. Differences in PISA test scores between the study programs were assessed using the Kruskal-Wallis test, as the data were non-normally distributed. To compare the scores of first-year pre-service teachers with those of third-year pre-service teachers and professional teachers, post-hoc tests were used to identify significant differences between the groups. For the qualitative analysis, participants' responses to free-response questions were analyzed using thematic analysis. This involved identifying recurring themes in their answers, such as cognitive challenges, critical thinking, and engagement with the PISA tasks. The analysis was conducted iteratively, with regular reviews of the data to ensure accurate representation of the participants' experiences.

Ethical considerations were strictly adhered to throughout the study. Participants were informed about the purpose of the research, the voluntary nature of their participation, and their right to withdraw at any time without consequence.

All responses were anonymized to maintain confidentiality, and the data were used solely for the purposes of this study.

## RESULTS AND DISCUSSION

Quantitative and qualitative data were obtained from the test results and the answers to the free response questions. The data were then processed and analyzed, the results of which can be seen in the research results section and discussed comprehensively in the discussion section.

### Research Results

#### Comparison of PISA Test Scores by Gender

Based on the test results of first-year science pre-service teachers, the following data were obtained. To determine whether there is a significant difference between the acquisition of PISA test scores in terms of gender, the student-t test will be used. The following statistics on the acquisition of PISA scores for each gender can be seen in [Table 1].

Table 1. Average and Standard Deviation of Male and Female Scores

Gender	Frequency	Average	Standard Deviation
Male	55	8,13	3,873
Female	98	7,61	3,713

Before conducting the t-test, it must first be checked whether the PISA scores for each gender are normally distributed. Since both genders have a high frequency, normality testing can be done using the Kolmogorov-Smirnov test. The test results can be seen as in [Table 2].

Table 2. Normality Testing Table Using Kolmogorov-Smirnov Test

Gender	Significance
Male	0,040
Female	0,000

Because the data meets the assumption of normality, then the t-test will be conducted. The results can be seen in [Table 3]. In the table, the assumption of homogeneity of variance is also met. Furthermore, the t-test indicates that there is no significant average difference between the PISA test scores in terms of gender.

Table 3. Table Testing the Equality of Means Using the T-Test

Levene's Test for Equality of Variance		T-test for Equality of Means	
F	Significance	t	Significance
0,355	0,552	0,811	0,419

#### Comparison of PISA Test Scores by Study Program

To determine whether there is a significant difference between the acquisition of PISA test scores in terms of study programs, ANOVA test or Kruskal-Wallis's test will be used, depending on the results of the ANOVA assumption test. The

following statistics on the PISA scores for each participating study program can be seen in [Table 4].

Table 4. PISA Score Statistics for Each Study Program

Study Program	Frequency	Average	Standard Deviation
Educ. Mathematics	54	7,61	3,350
Educ. Biology	25	9,28	4,713
Ed. Physics	13	6,15	3,211
Ed. Computer	61	7,70	3,680

Before conducting the ANOVA test, it must first be checked whether the PISA scores for each group are normally distributed. Since there are some groups that have high frequencies and some groups that have low frequencies, normality testing can be done using Kolmogorov-Smirnov test and Shapiro-Wilk test at the same time. The test results can be seen as in [Table 5].

Table 5. Normality Testing Table Using Kolmogorov-Smirnov and Shapiro-Wilk

Study Program	Significance (Kolmogorov-Smirnov test)	Significance (Shapiro-Wilk Test)
Educ. Mathematics	0,002	0,002
Educ. Biology	0,082	0,063
Ed. Physics	0,200	0,754
Ed. Computer	0,000	0,000

Because there were several groups that were not normally distributed, both using the Kolmogorov-Smirnov test and the Shapiro-Wilk test, the ANOVA test could not be performed. Alternatively, the Kruskal-Walli's test could be conducted. The results can be seen in [Table 6].

Table 6. Participant Score Distribution Testing Table for Each Study Program

Test Statistic	Significance
4,167	0,244

In the table 6, it can be seen that the Kruskal-Walli's test indicates that the distribution of participants' PISA scores for each study program is significantly the same. In other words, there is no significant difference in the distribution of participants' PISA scores for each study program.

### **Comparison of PISA Test Scores by Study Program; Comparison of PISA Test Scores by Level of Professionalism**

To determine whether there is a significant difference between the acquisition of PISA test scores in terms of the level of professionalism of the participants, ANOVA test or Kruskal-Walli's test will be used, depending on the results of the

ANOVA assumption test. The following statistics on the PISA scores for each level of professionalism can be seen in [Table 7].

Table 7. PISA Score Statistics for Each Level of Professionalism

Professionalism Level	Frequency	Average	Standard Deviation
First-year science pre-service teachers (Freshmen)	153	7,80	3,767
Third-year science pre-service teachers (Junior)	19	9,37	2,852
Professional Teacher	31	8,29	2,747

Before conducting the ANOVA test, it must first be checked whether the PISA scores for each group are normally distributed. Since there are some groups that have high frequencies and some groups that have low frequencies, normality testing can be done using Kolmogorov-Smirnov test and Shapiro-Wilk test at the same time. The test results can be seen as in [Table 8].

Table 8. Normality Testing Table Using Kolmogorov-Smirnov and Shapiro-Wilk

Professionalism level	Significance (Kolmogorov-Smirnov test)	Significance (Shapiro-Wilk Test)
First-year science pre-service teachers (Freshmen)	0,000	0,000
Third-year science pre-service teachers (Junior)	0,094	0,153
Professional Teachers	0,200	0,860

Because there were several groups that were not normally distributed, both using the Kolmogorov-Smirnov test and the Shapiro-Wilk test, the ANOVA test could not be performed. Alternatively, the Kruskal-Wallis's test could be conducted. The results can be seen in [Table 9]. In the table, it can be seen that the Kruskal-Wallis's test indicates that the distribution of participants' scores for each study program is significantly different.

Table 9. Participant Score Distribution Testing Table for Each Level of Professionalism

Test Statistic	Significance
6,334	0,042

Next, a post-hoc test will be conducted to determine which study programs have different score distributions. The results can be seen in [Table 10]. In this table 10, the significantly different score distribution is the First-year science pre-service teachers with Third-year science pre-service teachers' pair.

Table 10. Post-Hoc Test Table

Professionalism level	Test Statistic	Significance
First-year science pre-service teachers - Professional Teachers	-16,155	0,161
First-year science pre-service teachers - Third-year science pre-service teachers	-32,161	0,024
Third-year science pre-service teachers - Professional Teachers	16,007	0,347

### First-year science pre-service teachers' perspectives on PISA characterization questions

Table 11 summarizes first-year science pre-service teachers' responses to PISA characterization questions. It emphasizes multiple themes: cognitive challenges, critical thinking and problem-solving, frustration and unfamiliarity, applicability and relevance, and engagement. These insights provide a deeper understanding of their engagement and perceptions.

Table 11. Key themes from First-Year Science Pre-Service Teachers' Responses to PISA Characterization Questions

Theme	Participant Perspectives	Comments/Examples
Cognitive Challenge	Many participants found the questions difficult or challenging, using terms like "hard," "complicated," and "brain-draining."	<p><i>"It's hard"</i></p> <p><i>"It's very brain-draining"</i></p> <p><i>"It's complicated for me"</i></p> <p><i>"It's hard because I've never studied before"</i></p> <p><i>"Need accuracy to answer the questions"</i></p>
Critical Thinking and Problem-Solving	Respondents praised the questions for testing higher-order thinking skills (HOTS), requiring analysis and logical reasoning.	<p><i>"Testing us to think more and be more thorough"</i></p> <p><i>"Questions like this help students to understand, make us think critically"</i></p> <p><i>"Very good at testing brain intelligence"</i></p> <p><i>"These questions emphasize analytical thinking skills"</i></p>
Frustration and Unfamiliarity	Some participants were unfamiliar with the format of PISA questions, leading to confusion.	<p><i>"I don't understand the questions"</i></p> <p><i>"Not too familiar with the question"</i></p> <p><i>"Difficulty in interpreting what was asked"</i></p> <p><i>"Confused to understand the question"</i></p>

Applicability and Relevance	Several respondents appreciated the relevance of PISA questions in real-world applications, especially in science and everyday life.	<i>"It tests students' ability to apply knowledge"</i> <i>"The questions are very useful for everyday life"</i> <i>"PISA character questions play heavily on logic and place great importance on literacy"</i>
Engagement	Despite the difficulty, many respondents found the questions engaging and exciting.	<i>"Fun but tricky"</i> <i>"The questions are very exciting and fun"</i> <i>"Very exciting and made us gain insight"</i> <i>"Great, really requires focus"</i>

Table 12 presents the perspectives of third-year pre-service science teachers and junior high school science teachers on PISA characterization questions, based on responses from previous studies (Agustiani, 2020). The table summarizes their views on the difficulty, time constraints, and the level of critical thinking required by these questions.

Table 12. Perspectives of Third-Year Pre-Service and Junior High School Science Teachers on PISA Characterization Questions (Agustiani, 2020)

Group	Comments
Third-Year Pre-Service Teachers	<i>"The questions seem easy, but the answers can be misleading if not careful."</i> <i>"The questions test HOTS (Higher Order Thinking Skills), with varying levels of difficulty."</i> <i>"The information in the questions is very long, and it takes time to read them."</i> <i>"The questions make us learn to analyze, even though there are already guidelines beforehand."</i> <i>"The questions are good, containing many distractions, and require understanding and analysis."</i> <i>"The questions provide relevant information, but the time given is insufficient."</i> <i>"The questions present problems and lead to research, so we must think logically."</i>
Junior High School Teachers	<i>"The questions are too difficult, the sentences are too long, making them confusing."</i> <i>"The questions are very good, analytical, and challenging, but the time is not enough to complete them."</i> <i>"The questions are very HOTS!"</i> <i>"The stimulus narrative is very long, so it needs to be read repeatedly."</i> <i>"The questions are only for highly intelligent students,"</i>

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*not all students can be given these questions.”*

*“Working on the questions requires layered analysis by integrating various related knowledge.”*

*“Once you understand the questions, it turns out that answering them is not difficult!”*

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## **Discussion**

This study found that gender had no significant effect on the PISA scores of first-year science pre-service teachers. This result is quite different from previous studies, which found that boys tend to perform lower in subjects such as reading and science. The study showed that girls were more diligent in allocating study time for these subjects, resulting in higher scores. The study analyzed Indonesian children tested on the PISA test, showing that gender played an important factor in their PISA performance, with girls outperforming boys due to more structured study habit (Ulkhay, 2024). Other studies also show that there is a serious global pattern of boys' low achievement in reading and their low engagement in reading, compared to girls (Brozo et al., 2014). Another study that looked at Italian students, also showed that girls tend to display positive behaviors, which correlate with higher academic achievement than boys in standardized tests such as PISA (Mento et al., 2024). Another study found that boys have an advantage in math problems, especially in the concepts of space and shape. The study showed a slight but consistent male advantage in math concepts (Liu & Wilson, 2009). This study is also supported by other studies, which show that girls are less interested in STEM careers due to lower motivation in math. Uniquely, however, analysis of PISA standardized tests on first-year science pre-service teachers showed no significant difference in their performance. This result could be because pre-service teachers are more emotionally stable and have better basic literacy and math skills than they did as children, both men and women. There is a study that found that when individuals reach higher levels of education, such as teacher training programs, the performance differences between genders in subjects like math significantly narrow. This is consistent with our findings that first-year science pre-service teachers, regardless of gender, show no significant performance differences in standardized tests like PISA. The study suggests that emotional maturity, academic development, and increased self-awareness contribute to this equalization of performance. First-year science pre-service teachers are also less influenced by stereotypes compared to younger students, which may explain the more balanced academic outcomes (Lindner et al., 2022).

Analysis of the effect of the study program on the PISA score of pre-service teachers also showed no significant difference. This result could be since each study program teaches how to think critically and analytically, so there is no significant difference, considering the scientific thinking approach is the same. Previous studies have also shown that general school conditions, rather than the specific educational program (e.g. mathematics vs biology), play a more prominent role in determining PISA scores (You et al., 2021). This is also supported by the ability of first-year science pre-service teachers, who have taken and completed general education during primary, secondary and senior high school. All received the same baseline, thus showing PISA scores that were not significantly different. Another study showed that PISA scores, rather than reflecting specialized expertise in a

particular field, are strong predictors of general academic success and proficiency across a range of subjects (Fischbach et al., 2013). Their study found that higher PISA proficiency scores are associated with better educational outcomes, including grade promotion and final exam results, and that this predictive power remains strong even when controlling for socioeconomic factors. In addition, their findings suggest that PISA proficiency scores have limited discriminant validity, indicating that they reflect general cognitive ability rather than subject-specific knowledge. This supports our conclusion that students from different disciplines show similar PISA performance, which further strengthens the argument that PISA primarily measures broad academic and problem-solving competencies rather than expertise related to a specific field of study.

Analysis of first-year science pre-service teachers showed that their average scores were significantly lower than those of third-year science pre-service teachers. This result could be due to the fact that first-year science pre-service teachers are still in the transitional stage from senior high school, where they are still carrying over the nature and style of learning during senior high school, and have not been able to maximize their time for learning (Darmiany, 2016). Third year science pre-service teachers, on the other hand, have had longer experience learning and thinking scientifically during their studies, which could be the reason why their PISA scores are higher than first year science pre-service teachers. However, what is unique here is that the scores of first-year science pre-service teachers are not significantly different from the scores of professional teachers who have been teaching in schools. These results provide an overview of the current quality of professional teachers in Indonesia, where there are concerns about the low quality of teachers in Indonesia. This is supported by previous studies which revealed that less than half of teachers in Indonesia meet the minimum qualifications (Narmamatovich Shaturaev, 2021), a lot of teachers still do not meet the minimum standard of S1 or D4, especially in the less affluent areas (Wulan, 2024). The results of this study are in line with our findings, where the PISA scores of professional teachers show that the abilities of professional teachers are like the basic abilities of first-year science pre-service teachers, who are not yet proficient in working on PISA-characterized questions that emphasize analysis and literacy. These results encourage the Indonesian government to seriously improve the quality of pre-service science teachers and also the quality of teachers who are already teaching in schools, considering that teachers are the main key in educating the nation's generation in Indonesia (Maure et al., 2021). There is no significant difference between the scores of first-year science pre-service teachers and those of teachers already teaching in schools, suggesting that teacher training programs are important to improve the quality of teachers in Indonesia. The training program is proven to improve teachers' ability to read, ability to complete reading tasks such as those on PISA (Emilia et al., 2022). Not only to teachers who have been teaching in schools, but it is also important to pay attention to first-year science pre-service teachers, who are just entering the world of lectures. The lack of understanding and basic skills needs to be a concern for educators and policy makers to create programs and guidance for first-year science pre-service teachers to significantly improve their literacy and numeracy skills. Guidance from the beginning is expected to improve the quality of first-year science pre-service teachers, so that in

the future it can produce quality teachers who are able to boost education in Indonesia.

From the responses of first-year science pre-service teachers, there is a similar pattern with the perspectives of third-year science pre-service teachers and professional teachers. They agreed that PISA questions invite students to think deeply and analyze carefully and thoroughly (Agustiani, 2020). When compared with the perspectives of third-year science pre-service teachers from previous studies, there are some unique answer patterns, for example, many first-year science pre-service teachers feel difficulty and confusion in working on PISA-characterized questions, "I don't understand the questions". Whereas in the third-year science pre-service teachers, rarely did anyone say they did not understand the questions, but they emphasized the importance of accuracy and advanced thinking. This result is in line with the quantitative analysis, where the PISA score of first-year science pre-service teachers is significantly lower than that of third-year science pre-service teachers. These results suggest that first-year science pre-service teachers need special attention and maximum learning support, especially to train their literacy and analytical power. Many first-year pre-service teachers in our study expressed confusion and unfamiliarity with the PISA question format, which led to frustration. Comments such as "I don't understand the questions" and "I'm not familiar with the question" show that the novelty of the question style added to their difficulty. Other study also found that pre-service teachers also encountered frustration when faced with unfamiliar or poorly explained mathematical content (Itter & Meyers, 2017). Their negative attitudes were often tied to experiences where they felt lost or unable to keep up with the pace of the lesson, particularly as the curriculum shifted to more abstract and less engaging topics.

Some pre-service teachers also mentioned that the questions characterized by PISA are very relevant and applicable to everyday life. This is supported by the study which noted that PISA places significant emphasis on practical problem-solving skills, requiring students to use their scientific understanding to address problems they may face in everyday life (Lau, 2009). Fensham's paper looks at how PISA integrates real-world contexts into its science assessments, with a particular focus on how this approach influences science education (Fensham, 2009). The study argues that by using real-world scenarios, PISA helps bridge the gap between classroom learning and practical application. Harlen highlights that PISA's goal is to evaluate students' understanding of science not just in theoretical terms, but in how they can use scientific principles to navigate and solve everyday challenges (Harlen, 2001). This ensures that students are tested not only on their theoretical understanding of scientific concepts but also on their ability to use this knowledge in everyday situations.

The study is limited to first-year science pre-service teachers from a single university (Mulawarman University), which may not represent the broader population of pre-service teachers across Indonesia contexts. Findings might not be generalizable to other teacher education programs, disciplines, or cultural contexts outside of Indonesia. Broader participants will be future direction this exploratory research.

## CONCLUSION

This study aimed to explore the PISA test scores and perspectives of first-year science pre-service teachers in Indonesia, with a focus on gender, study program, and level of professionalism. The results indicate no significant differences in PISA scores between male and female participants, suggesting that gender does not influence the ability to perform on the test. Additionally, no significant differences in PISA scores were found across the four study programs, implying that students from different educational backgrounds perform similarly on the PISA test. However, the comparison of first-year science pre-service teachers with third-year students and professional teachers revealed significant differences, with third-year students scoring higher. Qualitative data highlighted that first-year pre-service teachers found the PISA questions challenging but acknowledged their value in promoting critical thinking and real-world applicability. These findings underscore the importance of integrating higher-order thinking skills into teacher education programs and suggest that further support is needed to prepare future educators for global standards in assessment, such as those set by PISA.

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