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The assessment of student numeracy ability for sustainable learning in Indonesia: A study in a high school science class

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Abstract: This study aimed to measure student numeracy ability within the context of physics on the kinetic theory of gases. This study employed a quantitative method with descriptive and parametric statistics analysis. Sixty-two sample students were measured for numeracy ability. The research instrument applied was the ten numeration questions that had been tested empirically. The research indicates that the student cognitive level positively influences numeracy ability with an effect size value of 0.682 and an Adj. R^2 value of 0.676. Furthermore, gender-related analysis proves that there is no gap in the numeracy ability with an effect size value of 0.030 and Adj. R2 is 0.014. This study has implications for designing physics learning that develops numeracy ability, especially in determining learning designs that accommodate cognition level and gender.
Keywords: Assessment Competence Minimum; Assessment and Evaluation; Numeracy Ability

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Introduction

Education in Indonesia has gotten into a new era by implementing the “Merdeka” curriculum since 2019. One of the significant policies was to eliminate the national final exam (national exam) implemented since 2003 with a minimum competence assessment (AKM). The national exam is considered ineffective in evaluating the learning process because the quality of the school is represented only by the ability of students to answer a set of questions (Murtiana, 2011; Syahidu et al., 2022). Besides, there are so many factors to determine the quality of learning in a school.

AKM is designed to evaluate learning from the perspective of teachers and students. AKM is expected to explore the quality of education in Indonesia more representative. In AKM, students are measured from two aspects: cognitive competence consisting of literacy and numeracy abilities, and character by measuring attitudes, habits, and values. The focus of measuring cognitive ability is also different from the national exam. For example, the national exam focuses on conducting multiple-choice tests using a computer-based test scheme, while the AKM adapts the assessment scheme developed by PISA with various forms, i.e., multiple-choice, complex multiple-choice, matchmaking, short entry, and descriptions (Widarti et al., 2022). Furthermore, the AKM test implementation scheme also adopted a test in the form of a computerized adaptive test (Gao et al., 2020).

Cognitive assessment in the AKM framework was developed due to dissatisfaction with the results of the international scale measurement in PISA/ TIMMS. In the last two decades, the PISA scores obtained by Indonesian students are still appalling (Brault Foisy et al., 2015; Bunawan et al., 2019;

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Fenanlampir et al., 2019; Stacey, 2011; Zulkardi et al., 2020). The reason is that the form of assessment developed and applied at the school and national level is not yet compatible with the forms of the tests in PISA and TIMMS. Hence, the literacy and numeracy aspects that are part of the tests in PISA and TIMMS are further adapted in the AKM. By optimizing AKM, students are expected to be familiar with the problems presented in PISA/TIMMS. Therefore, Indonesian students can achieve better scores in the next PISA/TIMMS test.

Aspects of literacy, especially scientific literacy, are already quite popular in Indonesian education and research. For example, the previous researchers focus on the measurement of scientific literacy (Astari et al., 2018; Sholikah & Pertiwi, 2021), item development (Rokhmah et al., 2017), and learning designs that can improve students' scientific literacy ability (Herlanti et al., 2019; Pursitasari et al., 2019; Rusilowati et al., 2016). In contrast, research on students' numeracy ability is still limited. The debate on the subject of numeracy is still a debate. Some education practitioners think numeracy is the mathematics subject's responsibility (Callingham et al., 2015; Coffey & Sharpe, 2021). At the same time, the other group assumes that numeracy is the responsibility of a cognitive scientific group. Regardless of the debate, numeracy is essential in studying physics (Delialioğlu & Aşkar, 1999; Retnawati et al., 2018). Many studies have proven that the success of learning physics is determined by mathematical ability, which is included in numeracy.

The relationship between mathematical ability and success in learning physics is the first step teachers need to be aware of, especially in determining the numeracy aspects to develop. The initial step is mapping student numeracy ability using a numeracy assessment framework. Furthermore, these results can be used as a reference to improve the quality of learning, especially for practising numeracy ability. Therefore, this study aims to measure student numeracy ability in Indonesian secondary schools that provide an overview of the quality of physics learning. Three research questions are discussed in this study, including 1) How is the quality of numeracy instruments? 2) What is the profile of students' numeracy abilities regarding cognitive level aspects?; and 3) What is the student's numeracy ability profile based on gender?.

Method

This quantitative research measured student numeracy ability without giving any treatment first. Ignoring the intervention factor is intended to analyze school quality in learning physics. Participants in this study were 62 students consisting of 29 male and 33 female students. The characteristics of the participants in this study are presented in Table 1.

Table 1. Sample Demography

Criteria	n	%	Age (years)	Levels (n)		
				High	Middle	Low
Male	29	47	17-18	19	10	-
Female	33	53		16	17	-

The grouping of students into three levels (high, middle, and low) is based on the ability test carried out through the following Standard Deviation Ideal (SDI) equation (Dixson & Massy, 1997). Student ability is then categorized based on Table 2.

$$M_i = \frac{1}{2}(\text{Maximum Score Ideal + Minimum Score Ideal}) \quad (1)$$

$$SD_i = \frac{1}{6}(\text{Maximum Score Ideal} - \text{Minimum Score Ideal}) \quad (2)$$

Table 2. Student-Level Cognitive Categories

Score	Category
X > Mi + 0,5 SBi	High
Mi + 0,5 SBi > X > Mi - 0,5 SBi	Middle
Mi - 0,5 SBi > X	Low

The research instrument used was a numeracy test sheet given to students. Ten numeracy questions were developed referring to the numeracy assessment framework. The questions were developed with the subject of physics on the kinetic theory of gases (TKG). This topic was chosen because it is rarely studied in most physics research, especially the discussion of numeracy. Whereas, in the learning process, the topic of TKG is very familiar with a mathematical approach compared to an analytical approach. In addition, the research time factor also influences the selection of research topics. The measurement data were analyzed using descriptive analysis to explore student numeracy ability. The following analysis was to analyze the measurement data using statistical tests to see the contribution of cognitive level and gender to numeracy ability. The test carried out is univariate parametric statistics with effect size analysis with parameter estimate.

Results and Discussion

Instrument Quality (RQ1)

The quality test instrument is crucial in indicating the validity and reliability of cognitive measurement. In this study, the test instrument was developed by referring to the numerical assessment framework in the AKM. The instruments consist of ten numeracy questions of TKG. The description of the items is provided in Table 3.

Table 3. Numeracy test instrumen

Competence	Item Indicator	Cognitive Dimension	Cognitive Process
Explain the kinetic theory of gases and the characteristics of gases in an enclosed space	Students can compare the mass of gas in a system of gas kinetic theory	Compare	Factual
	Students can formulate general equations for the kinetic theory of gases	Analyze	Conceptual
	Students can solve problems using the general equations of the kinetic theory of gases	Apply	Factual
	Students can determine the dimensions of the kinetic theory of gas equations	Analyze	Conceptual
	Students can represent the general equations of the kinetic theory of gases	Interpret	Conceptual
	Students can apply the understanding of the concept of the kinetic theory of gases in everyday life	Apply	Factual
	Students can determine the graph on the kinetic theory of gas equations	Analyze	Conceptual
	Students can analyze the energy in gases using the energy equation in an ideal gas	Analyze	Conceptual
	Students can be skilled in using the general ideal gas equation in some instances	Apply	Conceptual
	Students can apply the velocity equation of ideal gas particles	Apply	Conceptual

The test instrument consisting of 10 essay questions was then tested on students to obtain empirical validity and estimate the reliability value of the instrument. Item quality analysis was carried out using item response theory (IRT), as seen in Table 4.

Table 4. Summary Statistic of Instrument Quality

Variables	Score
INFIT MNSQ	0.97
OUTFIT ZSTD	-0.20
Average Difficulty Level	0.00
Separation	1.40
Strata Separation	2.20

Variables	Score
Item Reliability	0.66
KR-20 Test Reliability	0.92
RMSQ	0.30

Cognitive Level Analysis (RQ2)

Instruments declared empirically feasible are then used to measure student numeracy ability. The measurement results show that student numeracy ability is at a moderate level, with an average score of 69.81 out of 100. However, this study describes the measurement results through cognitive and gender levels. The level of cognitive analysis is contained inTable 5.

Table 5. The Effect of Cognitive Level on Numeracy Ability

No	Cognitive Level	Score	Std Error	Shapiro-Wilk	Lavenes Test	effect size	Sig.	Adj. R^2
1	High	74.51	0.51	0.095	0.090	0.682	0.00	0.676
2	Middle	63.70	0.85	0.039				

Table 5 indicates that only two groups of students are participants in this study: high cognitive levels (HCL) and moderate cognitive levels (MCL). The first result is the scores obtained in both groups, where HCL students get a higher score than those MCL students. In addition, the measurement results are considered precise, with the resulting standard error value being relatively small, below 1%. Furthermore, the numerical measurement error in HCL students is 0.51%, and the measurement error in MCL students is 0.85%.

The measurement results, which showed differences in ability in the two groups, were then analyzed using parametric statistics. The initial stage is to conduct prerequisite tests in normality and homogeneity. The Shapiro-Wilk and Levene's Test values presented in Table 5 indicate that the analyzed data met the normal distributed and homogeneous criteria. Therefore, the statistical test carried out is parametric statistics, namely the univariate test. The significance value generated on the univariate test showed a significant difference in the two groups at the 5% confidence level (sig. < 0.05).

The significant difference between the two test groups indicated that cognitive level affected numeracy ability. The effect size value of 0.682 provides information that the contribution given by the cognitive level factor is a significat effect. This value is also proven by Adj. R^2 of 0.676 means that the contribution to the cognitive level of numeracy ability is 67.6%. To obtain further information on the effect of cognitive level, Table 6 provides information on the measurement results for each aspect of numeracy.

Table 6. The analysis of cognitive level on numeracy aspects

No	Cognitive Level	Cognitive Dimension				Cognitive Process	
		Comparing	Analyzing	Applying	Interpreting	Factual	Conceptual
1	High	7.31	7.52	7.39	7.54	7.34	7.50
2	Middle	6.44	6.39	6.35	6.37	6.38	6.38

The information in Table 6 can be categorized into two information groups, namely cognitive dimensions and cognitive processes. Table 6 clearly shows that in every aspect of numeracy, the HCL students get higher scores than the MCL students.

Gender Analysis (RQ3)

The following analysis deals with numeracy abilities by gender. There are two gender groups analyzed in this study, namely male and female. The results of the analysis of gender factors are in Table 7.

Table 7. Gender Analysis on Numeracy Ability

No	Gender	Score	Std Error	Shapiro-Wilk	Lavene's Test	effect size	Sig.	Adj. R^2
1	Male	71.00	1.04	0.057	0.060	0.030	0.180	0.014
2	Female	68.76	1.26	0.434				

The data in Table 7 shows that there is almost no significant difference in numeracy ability between male and female students. The difference in the mean score obtained is only 2.24 out of 100, which is relatively small, with a measurement error of 1.15%. The measurement error is very close to the difference in the measurement results. Although there is no apparent difference, this study still performs further analysis using parametric statistics in the form of a univariate test. This test is based on the fulfilment of the prerequisite test through the Shapiro-Wilk test and Levene's test, indicating that the analyzed group values are normally distributed and homogeneous.

The previous statement was proven through the significance value on the univariate test 0.180 > 0.05. This score indicates that there is no significant difference between the two groups tested, in this case, male and female student abilities. This finding is confirmed by the minimal effect size value of 0.03 and the Adj. R^2 is 0.014. In other words, the gender factor only affects the numeracy ability by 1.4%. Further analysis related to the aspect of numeracy is contained in Table 8.

Table 8. The analysis of gender in numeracy aspects

No	Gender	Cognitive Dimension				Cognitive Process	
		Comparing	Analyzing	Applying	Interpreting	Factual	Conceptual
1	Male	7.10	7.15	7.03	7.14	7.05	7.11
2	Female	6.79	6.92	6.86	6.93	6.80	6.91

Table 8 proves that the numeracy ability of male students is better than that of female students. In every measurement aspect, male students scored better than female students. However, though it is not significantly different, this proves that the innate abilities of male students tend to be better than female students in the numeracy context.

Discussion

Numerical ability is currently one of the main concerns of education in Indonesia. However, numeracy is not a new matter in the context of learning physics. Before the emergence of the numeracy component in the AKM assessment framework, physics learning already used mathematical operations to solve problems (Madison & Steen, 2007; Phoenix, 1999). The difference lies in the focus of the study, where previously, the context of numeracy in physics learning was still focused on theoretical problems, especially in secondary schools (Brogt et al., 2014; Hadley & Oyetunji, 2022; Kalender et al., 2019; Smith, 2003). Meanwhile, in the context of AKM, numeracy is faced with real problems to be solved using mathematical operations. Therefore, the context of numeracy in physics learning needs to be realigned.

The findings indicate that student numeracy abilities are at a moderate level. The results are relatively not bad considering the limitations of students experienced in learning physics due to the Covid-19 pandemic. The analysis of student abilities based on cognitive level proves that cognitive level influences student numeracy ability. The statistical test results in Table 5 indicate that HCL students have higher numeracy scores. This result indicates that numeracy abilities have the same tendency as abilities in general. Theoretically, the HCL make student easier to understand the context of the problem (Adeoye, 2010; Cohen et al., 1978; Mufit et al., 2020). At the same time, understanding the context of the problem is essential in solving numeracy problems since problems are relatively complex.

The HCL students dominate in every aspect analyzed. In the measurement result scores, the HCL students get 10.81 points higher than the MCL students. A similar result was also found in the cognitive domain, where the HCL students got 10.5 points higher than the MCL students. While in the aspect of cognitive processes, the HCL students also got 10.5 points higher than the MCL student. The scores for these three aspects are shown in Figure 1.

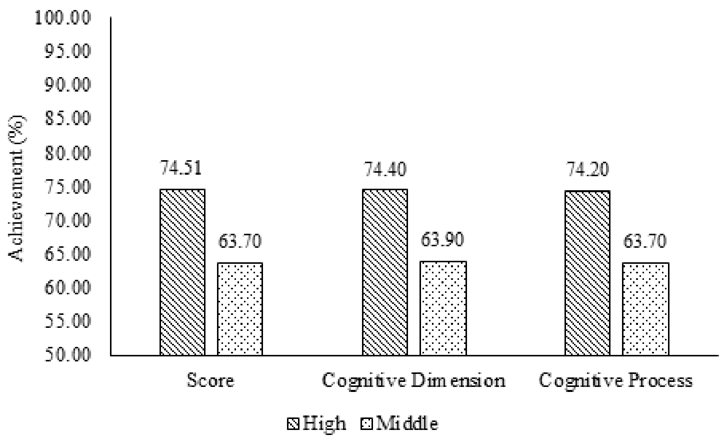

Figure 1. Student achievement – Cognitive level analysis

The following analysis deals with the influence of gender. In education, research on gender has a relatively high appeal. This is due to psychological findings showing that a primary mindset distinguishes male and female students (Kalender et al., 2022; Kleinfeld, 2009). In physics, many researchers have proven the influence of gender on learning success (Gunawan et al., 2020; Herliana et al., 2020; Sun, 2020). On the other hand, many studies also prove that gender is not too influential (reduced) in the success of learning physics (Gunawan et al., 2020; Herliana et al., 2020; Sun, 2020).

The results of this study have relatively the same indications as the second finding, which prove that there is no significant gender difference in numeracy ability. A recapitulation of findings related to gender differences is shown in Figure 2.

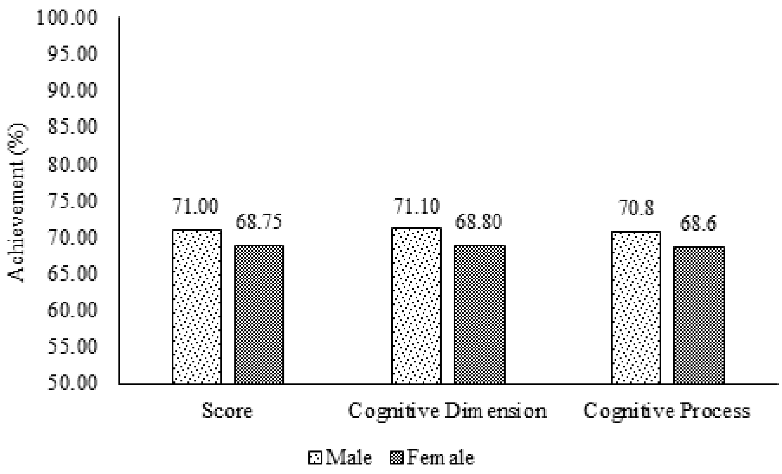

Figure 2. Student achievement – Gender analysis

Figure 2 shows that male students have higher scores than female students. However, this difference is insignificant, with only a 2.25-point lead. Moreover, considering the error of measurement of 1.15%, the abilities of male and female students may be the same. Furthermore, looking at the aspects of the cognitive dimensions, the difference in student abilities is only 2.30. Again, taking into account the measurement error value of 1.13%, this value could be the same. Hence, this finding supports previous research that gender does not affect the success of learning physics (Abdisa & Getinet, 2012; Herliana et al., 2020; Sagala et al., 2019).

Research findings related to the cognitive level and gender factors have implications for implementing physics learning in schools, especially in the provision of numeracy ability. In schools with heterogeneous student characteristics, teachers need to treat students with low cognitive levels differently. The treatment can be in the form of peer instruction, assignments, and remedial learning. In addition, teachers do not need to worry about grouping students based on gender because numeracy ability does not explicitly state that there is dominance by one gender in supporting learning success.

Conclusion

Numerical ability in the context of learning physics is needed because most of the facts, laws, and theories of physics are explained through a mathematical approach. Therefore, numeracy abilities are essential for students studying physics. On the other hand, research findings indicate a contribution from the cognitive level to student numeracy abilities. The significant difference in ability provides an advantage for students with a high cognitive level to understand the context of numeracy in learning physics. Another finding from this study proves that there is no significant difference between the numeracy abilities of male and female students. This finding is also an option for overcoming the gender gap problem in physics learning.

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