

Research article

Evaluating the Gender Gap in Academic Achievement: The Role of Household WASH Access in Indonesia

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ABSTRACT

This study investigates the association between access to improved water and sanitation (WASH) and the academic performance of students in Indonesia, as measured by national examination (UN/EBTANAS) scores in Mathematics, Indonesian, and English. Utilizing pooled cross-sectional data from the Indonesia Family Life Survey (IFLS) waves 1–5, the analysis employs Ordinary Least Squares (OLS) regressions incorporating gender interaction terms and a comprehensive suite of individual, household, and contextual control variables. The empirical results demonstrate that access to improved water and sanitation is positively and significantly associated with higher academic achievement. Notably, the association between improved water access and examination scores is significantly more pronounced for female students, particularly in Mathematics and English. In contrast, improved sanitation exhibits a positive but gender-neutral association across all subjects. The heightened benefits observed for female students may be attributed to a reduction in time burdens associated with domestic water collection and enhanced menstrual hygiene management, both of which serve to mitigate school absenteeism. These findings underscore the critical importance of integrating water and sanitation infrastructure improvements into broader education and gender-equity policies in Indonesia. This study contributes to the existing literature by providing robust, gender-disaggregated evidence of the impact of WASH infrastructure on standardized academic outcomes using longitudinal household survey data.

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1. INTRODUCTION

Quality education, gender equality, and access to clean water and sanitation represent three of the 17 interconnected Sustainable Development Goals (SDGs). Achieving clean water and sanitation (SDG 6) is instrumental in reaching other targets by 2030 (SIWI, 2024), most notably quality education (SDG 4) and gender equality (SDG 5). Specifically, access to clean water reduces the incidence of diarrheal diseases in children, which consequently decreases school absenteeism (Komarulzaman et al., 2019; WHO, 2023b). Conversely, a lack of access to clean water hinders educational optimization, as children may be required to spend time fetching water instead of studying and exacerbates gender inequalities, particularly affecting girls (SIWI, 2024; and WHO & UNICEF, 2023b). Globally, females aged 15 and older are responsible for water collection in approximately 70% of households relying on off-premise sources (WHO, 2023a). This unequal time allocation constrains girls' educational opportunities by reducing study time and increasing physical fatigue. Furthermore, limited water access can impair concentration, hydration, and cognitive functioning, thereby undermining academic performance (Chard et al., 2019). Inadequate access also contributes to higher absenteeism due to water-related illnesses like diarrhea, which disproportionately affect children (Dreibelbis et al., 2013; and Nauges & Strand, 2017). For girls, these challenges are compounded by insufficient water for menstrual health and hygiene, further increasing absences and limiting participation in learning activities (Phillips-Howard et al., 2016).

In Indonesia, these challenges are highly relevant as disparities in water access and gender equality remain significant concerns. Despite efforts to improve infrastructure, by 2022 only 30.3% of the Indonesian population had access to safely managed water, representing only a slight increase since 2002 (WHO & UNICEF, 2023a). Furthermore, gender disparities in education persist; in 2023, the average years of schooling were 9.33 for males compared to 8.92 for females (Badan Pusat Statistik, 2023). This inequality is reflected not only in educational access but also in quality, as evidenced by gender-based differences in PISA scores (OECD, 2023). A growing body of literature has examined the impact of water and sanitation access on education, consistently finding that improved access positively influences outcomes such as school attendance and cognitive development (Chard et al., 2019; Choudhuri & Desai, 2021; Nauges & Strand, 2017; Njoh et al., 2018; Santiago Ortiz-Correa et al., 2016; and Shimamura et al., 2022). In Indonesia, research underscores the critical role of water and sanitation in improving education both directly and indirectly, such as research by Komarulzaman et al. (2019); and Setyari et al. (2022). However, existing studies primarily focus on overall educational impacts without analyzing the magnitude of gender-based differences.

While most research utilizes indicators like school attendance, enrollment, and average years of schooling, few have examined the impact on direct academic performance, such as standardized test scores (Komarulzaman et al., 2019; Nauges & Strand, 2017; Njoh et al., 2018; Santiago Ortiz-Correa et al., 2016; and Shimamura et al., 2022). Only a limited number of studies, such as those conducted by Choudhuri & Desai (2021); and Setyari et al. (2022), have demonstrated the effect of clean water access on specific metrics like mathematics scores. This leaves a significant gap regarding the impact on other subjects, such as Indonesian and English, which could provide a more comprehensive understanding of the relationship between water access and academic achievement. Furthermore, much of the current literature focuses on participation indicators rather than direct measures of learning outcomes, which may not fully capture educational quality. This gap is particularly salient given that 2020 PISA scores in Indonesia showed that females outperformed males by 6 points in mathematics and 23 points in literacy, a trend that deviates from the global pattern where males often outperform females in mathematics (Bharadwaj et al., 2015; Dickerson et al., 2015; Fryer & Levitt, 2010; and OECD, 2023).

To address the limitations of participation-based metrics, this study utilizes standardized national examination (UN/EBTANAS) scores as a direct measure of academic performance. Unlike indicators such as school attendance or years of schooling, which may fail to reflect variations in educational quality, exam scores more precisely capture cognitive achievement and subject-specific learning outcomes. While the Indonesia Family Life Survey (IFLS) provides data on various educational outcomes, UN/EBTANAS scores offer a uniquely comparable and standardized metric for evaluating achievement across different cohorts and subjects. It is important to acknowledge that in large-scale household surveys like the IFLS, access to improved water and sanitation is typically measured through basic infrastructure indicators. These metrics may not fully account for actual water quality, quantity, or specific usage behaviors. Consequently, because the analysis relies on these infrastructure-based proxies, the estimated effects may actually understate the true correlation between Water, Sanitation, and Hygiene (WASH) access and academic performance. Accordingly, this study aims to analyze the association between access to improved water and sanitation and academic performance, with a specific focus on gender-based differences. The central hypothesis is that improved access to these facilities is associated with higher academic performance, particularly for females. This expectation stems from the fact that girls are often more adversely affected by limited access to water and sanitation, both through time-poverty and biological health requirements.

The remainder of the paper is organized as follows, section 2 details the data sources and empirical methodology; section 3 presents the results and provides a discussion of the findings; and section 4 concludes with a summary of policy implications.

2. RESEARCH METHODS

2.1. Data Collection

This study utilizes secondary data from the Indonesia Family Life Survey (IFLS), a comprehensive longitudinal dataset that captures detailed information on individuals, households, and communities across Indonesia. Conducted by RAND, the Center for Population and Policy Studies (CPPS) at Gadjah Mada

University, and SurveyMETER, the IFLS is representative of approximately 83% of the Indonesian population. As of 1993, the sample comprised 30,000 individuals across 13 of the country's 27 provinces, including North Sumatra, West Sumatra, South Sumatra, Lampung, DKI Jakarta, West Java, Central Java, DI Yogyakarta, East Java, Bali, West Nusa Tenggara, South Kalimantan, and South Sulawesi (Strauss et al., 2016).

The analysis draws on IFLS waves 1 (1993) through 5 (2014). National examination scores (UN/EBTANAS) are observed only once for each individual, corresponding to the year the examination was completed. To ensure contextual accuracy, water and sanitation variables are extracted from the IFLS wave chronologically closest to the student's examination year. Table 1 illustrates the classification of individuals by linking the timing of water and sanitation data to the corresponding UN/EBTANAS periods. While the authors initially explored a panel data approach using Fixed Effects (FE) models to leverage the longitudinal nature of the IFLS, this proved unfeasible. Because UN/EBTANAS scores are recorded only once per student, the lack of repeated academic observations precludes the use of FE estimation. Consequently, the study adopts a pooled cross-sectional Ordinary Least Squares (OLS) approach. OLS is employed to estimate the parameters of the linear regression model by minimizing the sum of squared residuals to achieve the best statistical fit (Wooldridge, 2016). This method is particularly suitable for estimating parameters with a conditional mean function, thereby predicting the average value of the dependent variable (y) based on the influence of the independent variables (x). Table 1 presents the classification of individuals by linking the year of water and sanitation information from IFLS to the corresponding period of UN/EBTANAS scores.

Table 1. Classification of individuals in the dataset

Year of Information on Water and Sanitation	UN/EBTANAS Scores
IFLS 1 : 1993	1993 – 1996
IFLS 2 : 1997	1997 – 1999
IFLS 3 : 2000	2000 – 2006
IFLS 4 : 2007	2007 – 2013
IFLS 5 : 2014	2014 – 2015

2.2. Model Specification

The analysis focuses on three core sub-scores of the UN/EBTANAS: Mathematics (unMTH), Indonesian (unIND), and English (unENG), each measured on a scale of 0 to 10. To examine potential heterogeneities, results are disaggregated by gender (female, male, and the aggregate sample). Accordingly, nine distinct econometric models are employed to evaluate the impact of access to clean water and sanitation on academic performance. The mathematical formulations for these models are defined as follows:

$$A_{i,j,s}^{f,m} = \alpha_1 + \beta_1 Water_{i,j} + \gamma_1 Sanitation_{i,j} + \theta_1 X_{i,j} + \varepsilon_{i,j} \quad (1)$$

Here, $A_{i,j,s}$ denotes the UN/EBTANAS score for individual i in household j for subject s (Mathematics, Indonesian, or English); notation f for female; and m for male; $Water_{i,j}$ and $Sanitation_{i,j}$ are binary indicators representing household access to improved water and sanitation infrastructure, respectively; $X_{i,j}$ represents a vector of individual- and household-level covariates; and $\varepsilon_{i,j}$ is the idiosyncratic error term. We employ nine distinct specifications to account for variation across academic subjects and gender. For gender-disaggregated models, the sample is partitioned into female (f) and male (m) cohorts.

It is acknowledged that access to improved water and sanitation is not exogenously assigned. Consequently, the estimated coefficients should be interpreted as associations rather than strictly causal effects. Furthermore, access to water and sanitation is proxied by household infrastructure indicators rather than direct measurements of water quality or actual consumption. This measurement limitation may lead to an attenuation bias in the estimated coefficients, suggesting that the reported results likely represent a lower-bound estimate of the true relationship between water, sanitation, and hygiene (WASH) access and academic performance. A detailed description of all dependent, independent, and control variables, along with their data sources, is presented in Table 2.

Table 2. The Description of Variables and Sources

Variables	Description	Source
Dependent Variable		
UN/EBTANAS Score ($A_{i,j,s}^{f,m}$)	Individual UN/EBTANAS examination scores in Mathematics, Indonesian, and English at the primary school (SD) and junior high school (SMP) levels. The variable is continuous.	IFLS Household Survey Book IIIA, Section DL
Independent Variables		
Improved Water Access (<i>Water</i>)	A binary variable equal to 1 if household <i>j</i> has access to improved drinking water sources as defined by WHO and UNICEF, including piped water, boreholes, protected wells, protected springs, rainwater, bottled water, or water delivered to the home; and 0 if the household relies on unimproved sources such as rivers, ponds, storage tanks, or other unimproved sources (UNICEF & WHO, 2023).	IFLS Household Survey Book II, Section KR
Improved Sanitation Access (<i>Sanitation</i>)	A binary variable equal to 1 if household <i>j</i> has access to improved sanitation facilities that hygienically separate human excreta from human contact, such as a private toilet with a septic tank; and 0 if the household uses unimproved sanitation facilities, including shared or public toilets, toilets without septic tanks, open defecation sites, or other unimproved facilities (UNICEF & WHO, 2023).	IFLS Household Survey Book II, Section KR
Control Variables ($X_{i,j}$)		
Year Difference	The difference in years between the year the UN/EBTANAS score was obtained and the closest available year of water and sanitation information in the IFLS survey. The variable ranges from 0 (same year) to 6 (six-year difference).	IFLS Book IIIA Section DL; Book II Section KR
Electricity Access	A dummy variable equal to 1 if the household has access to electricity and 0 otherwise.	IFLS Household Survey Book II, Section KR
Gender	A binary variable indicating the gender of the individual reporting the UN/EBTANAS score, coded as 1 for female and 0 for male.	IFLS Household Survey Book IIIA, Section COV
Education Level	The education level at which the UN/EBTANAS examination was taken, coded as 1 for primary school (SD), 2 for junior high school (SMP), and 3 for senior high school (SMA).	IFLS Household Survey Book IIIA, Section DL
Household Size	The total number of household members. This variable is continuous.	IFLS Household Survey Book K, Section AR
Number of Siblings	The total number of biological and step siblings of the individual classified as a child within the household. This variable is continuous.	IFLS Household Survey Book K, Section AR
Mother's Education	The highest number of years of schooling completed by the individual's mother. This variable is continuous.	IFLS Book IIIA Section DL; Book K Section AR
Place of Residence	A binary variable indicating the area of residence, coded as 1 for rural areas and 0 for urban areas.	IFLS Household Survey Book K, Section SC
Log per Capita Expenditure	The natural logarithm of household per capita expenditure, including food consumption, routine expenditures (e.g., electricity, water, fuel), long-term goods, education expenses, and housing costs.	IFLS Household Survey, Per Capita Expenditure (PCE)

Regarding sample attrition, the analysis is restricted to individuals with complete data for both UN/EBTANAS scores and key household characteristics within the corresponding IFLS wave. Because the outcome variable is observed only once per individual, attrition across subsequent IFLS waves does not bias the estimation through repeated observations; however, it may influence the sample composition across different cohorts.

3. RESULTS AND DISCUSSION

3.1. Results

This study employs a pooled cross-sectional approach, aggregating individual observations into a unified dataset. The initial sample comprised 24,389 individuals for the Mathematics examination, 25,223 for the Indonesian language test, and 16,119 for the English examination, drawn from a total of 53,238 households. During the data cleaning phase, observations with incomplete information across key variables were excluded to ensure robust estimation. As a result, the final analytical sample sizes vary across the UN/EBTANAS sub-scores, as detailed in Table 3. These variations are primarily attributable to missing components of the national examination scores for certain individuals at the time of the IFLS interviews. Table 3 provides a comprehensive summary of the descriptive statistics for all variables utilized in the analysis.

Table 3. Result of Descriptive Statistics

Variables	Mathematics		Indonesian		English	
	N	%	N	%	N	%
UN/EBTANAS scores (mean)	(6.16)	(1.86)	(6.89)	(1.27)	(6.14)	(1.69)
Improved Water & Improved Sanitation Characteristics						
Water access						
Unimproved water - base	494	3.36	503	3.32	256	2.70
Improved water	14,203	96.64	14,667	96.68	9,221	97.30
Sanitation access						
Unimproved sanitation - base	6,390	43.48	6,591	43.45	3,624	38.24
Improved sanitation	8,307	56.52	8,579	56.55	5,853	61.76
Individual Characteristics						
Gender						
Male – base	7,498	51.02	7,754	51.11	4,787	50.51
Females	7,199	48.98	7,416	48.89	4,690	49.49
Level of schooling						
Primary school – base	6,195	42.15	6,185	40.77	638	6.73
Junior high school	5,827	39.65	5,854	38.59	5,814	61.35
Senior high school	2,675	18.20	3,131	20.64	3,025	31.92
Household Characteristics						
Household size (mean)	(5.42)	(1.78)	(5.43)	(1.79)	(5.42)	(1.80)
Siblings size (mean)	(2.51)	(1.65)	(2.50)	(1.65)	(2.57)	(1.65)
Place of residence						
Urban – base	8,140	55.39	8,413	55.46	5,584	58.92
Rural	6,557	44.61	6,757	44.54	3,893	41.08
Electricity access						
Doesn't have electricity – base	1,090	7.42	1,117	7.36	429	4.53
Has electricity	13,607	92.58	14,053	92.64	9,048	95.47
Household's per capita expenditure (log)	(Rp 12.10)	(1.05)	(Rp 12.10)	(1.04)	(Rp 12.28)	(0.99)
Mother's years of schooling (mean)	(6.18)	(4.50)	(6.21)	(4.50)	6.66	(4.53)
Year of UN/EBTANAS						
1993 – 1996	2,465	16.77	2,558	16.86	1,068	11.27
1997 – 1999	2,290	15.58	2,299	15.15	2,388	14.65
2000 – 2006	4,456	30.32	4,754	31.34	3,231	34.1
2007 – 2013	4,873	33.17	4,943	32.59	3,189	33.66
2014 – 2015	613	4.17	616	4.06	601	5.34

Note: *N* is number of individuals; and % is the distribution percentage

Source: IFLS 1 – 5, processed

The average UN/EBTANAS scores presented in Table 3 reflect combined performance across primary, junior high, and senior high school levels. The mean scores range from a low of 6.14 in English to a peak of 6.89 in Indonesian. Regarding environmental factors, a high proportion of the sample (96% to 97%) reported access to improved water sources. Conversely, access to improved sanitation was substantially lower, prevalent in only 56% to 61% of the observed households. Meanwhile, to ensure the reliability of the estimated associations, it is necessary to account for the time elapsed between the IFLS survey waves and the students' national examination years. Table 4 presents the distribution of this temporal difference.

Table 4. Result of the Difference between the Year of the IFLS Survey and the Year of the UN/EBTANAS

Variables	Mathematics		Indonesian		English	
	N	%	N	%	N	%
0 years– base	3,453	23.49	3,545	23.37	2,435	25.69
1 years	2,328	15.84	2,381	15.70	1,208	12.75
2 years	2,572	17.50	2,662	17.55	1,485	15.67
3 years	2,144	14.59	2,201	14.51	1,217	12.84
4 years	1,490	10.14	1,537	10.13	906	9.56
5 years	1,461	9.94	1,531	10.09	1,097	11.58
6 years	1,249	8.50	1,313	8.66	1,129	11.91
Observations (N)	14,697		15,170		9,477	

Note: N is number of individuals; and % is the distribution percentage

Source: IFLS 1 – 5, processed

To examine the differential impacts of improved water and sanitation on females and males, we divided the sample into two groups and conducted separate regressions, as shown in Table 5. Additionally, the impacts of improved water and sanitation on the overall sample are analyzed, as presented in Table 6. The regression using the overall sample aims to determine whether there are significant differences between females and males with access to improved water and sanitation, utilizing interaction variables. It is essential to note that the regression results displayed in Table 5 and 6 present only the coefficients for the main variables of this study. Complete results, including all control variables, are provided in the Appendix A (Table A).

Table 5. Estimation Results by Gender

Variables	Female			Male		
	unMTH	unIND	unENG	unMTH	unIND	unENG
Main variables						
Water	0.353*** (3.42)	0.303*** (3.96)	0.189* (1.49)	0.027 (0.30)	0.195*** (2.50)	-0.075 (-0.54)
Sanitation	0.193*** (4.22)	0.162*** (5.31)	0.167*** (3.29)	0.135*** (3.07)	0.176*** (5.87)	0.190*** (3.84)
Constant	0.095 (0.30)	3.803*** (17.84)	-0.006 (-0.02)	-0.246 (-0.81)	3.464*** (16.50)	-1.018*** (-2.70)
Observations (N)	7,199	7,416	4,690	7,498	7,754	4,787
R ²	0.175	0.141	0.173	0.174	0.133	0.196

Notes: The dependent variables in this model are the UN/EBTANAS scores for Mathematics (unMTH), Indonesian (unIND), and English (unENG). The complete results of this estimation are presented in Appendix A. The t-statistic values for this model are indicated in parentheses. A one-tailed T-test is used for the improved water and improved sanitation variables. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. An F-test confirms that all independent and control variables are collectively significant at the 1% level.

Source: IFLS 1 – 5, processed

The results in Table 5 indicate that access to improved water is positively and significantly associated with all UN/EBTANAS sub-scores for females. Specifically, females with access to improved water score, on average, 0.353 points higher in Mathematics than their counterparts without such access. In contrast, for male students, improved water access is only significantly associated with Indonesian language scores, showing an average increase of 0.195 points. Regarding sanitation, improved facilities demonstrate a consistently positive and

significant effect on all examination scores for both genders. For female students, improved sanitation is associated with a 0.193-point increase in Mathematics scores, while male students exhibit a comparable increase of 0.135 points. These findings suggest that while improved sanitation yields broad academic benefits across genders, the impact of improved water may be more gender-sensitive.

Table 6. Estimation Results with the Full Sample

Variables	Without Interaction			With Interaction		
	unMTH	unIND	unENG	unMTH	unIND	unENG
Main variables						
Water	0.188*** (2.69)	0.248*** (4.53)	0.062 (0.66)	0.057 (0.62)	0.192*** (2.48)	-0.073 (-0.52)
Sanitation	0.163*** (5.15)	0.168*** (7.83)	0.176*** (4.98)	0.170*** (4.08)	0.171*** (5.94)	0.202*** (4.26)
Gender	0.079*** (2.85)	0.246*** (12.90)	0.084*** (2.68)	-0.166 (-1.25)	0.143 (1.35)	-0.129 (-0.70)
Constant	-0.134 (-0.61)	3.504*** (23.35)	-0.560** (-2.03)	-0.008 (-0.04)	3.557*** (22.31)	-0.446 (-1.51)
Interaction						
Water*female	-	-	-	0.262* (1.91)	0.110 (1.02)	0.251* (1.34)
Sanitation*female	-	-	-	-0.014 (-0.25)	-0.005 (-0.15)	-0.050 (-0.79)
Observations (<i>N</i>)	14,697	15,170	9,477	14,697	15,170	9,477
R ²	0.173	0.143	0.183	0.173	0.143	0.183

Note: The dependent variables in this model are the UN/EBTANAS scores for Mathematics (unMTH), Indonesian (unIND), and English (unENG). The complete results of this estimation are presented in Appendix B. The t-statistic values for this model are indicated in parentheses. A one-tailed t-test is used for the improved water; improved sanitation; Water*female; Sanitation*female variables. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. An F-test confirms that all independent and control variables are collectively significant at the 1% level.

Source: IFLS 1 – 5, processed.

The interaction between improved water and gender (Water*Female) reveals a significant gender-based disparity in academic benefits. Specifically, the results indicate that females with access to clean water achieve higher Mathematics scores by approximately 0.096 points and higher English scores by 0.122 points compared to their male counterparts. These findings suggest that while improved water access is a critical determinant of academic success for all students, it is particularly vital for the educational attainment of females. Conversely, the interaction between improved sanitation and gender (Sanitation*Female) is statistically insignificant across all three academic sub-scores. This indicates that the positive impact of improved sanitation on academic performance is uniform across genders, with no significant evidence of gender-based differences in how sanitation infrastructure influences national examination outcomes.

3.2. Discussion

The empirical analysis yields three primary findings. First, access to improved water and sanitation is positively and significantly associated with student academic performance across all subjects; individuals with superior WASH access consistently achieve higher UN/EBTANAS scores than those without. These results align with previous literature and support the study's initial hypotheses (Choudhuri & Desai, 2021; and Setyari et al., 2022). Second, the benefits of improved water access are significantly more pronounced for female students, revealing a distinct gender-differentiated effect. Third, improved sanitation exerts a positive but largely gender-neutral influence on academic outcomes. Collectively, these findings suggest that different components of WASH infrastructure influence educational performance through distinct socio-biological mechanisms.

Several pathways elucidate the positive influence of improved WASH access on academic achievement. Enhanced WASH infrastructure has been shown to increase school attendance (Komarulzaman et al., 2019; Nauges & Strand, 2017; and Santiago Ortiz-Correa et al., 2016), reduce the time burden of water collection,

thereby reallocating time toward learning, and lower the incidence of water-related illnesses such as diarrhea, cholera, and typhoid, which are primary drivers of absenteeism (McMichael, 2019; Setyari et al., 2022; Komarulzaman et al., 2017; and Santiago Ortiz-Correa et al., 2016). Furthermore, improved hydration from accessible water sources enhances concentration and cognitive functioning (Chard et al., 2019; and Setyari et al., 2022).

From a gendered perspective, the findings emphasize that while improved water access is essential for all students, it is particularly critical for females. Female students experience a sharper decline in UN/EBTANAS scores in the absence of adequate water, a disparity partly driven by the specific requirements of menstrual health and hygiene, consistent with previous studies by Choudhuri & Desai (2021); and Zhang & Xu (2016). Inadequate access often leads to infections and increased periodic absenteeism (Dreibelbis et al., 2013; and Maqbool et al., 2019). Moreover, in water-scarce environments, girls often bear a disproportionate responsibility for domestic water collection. Improved proximity to safe water reduces this time poverty, allowing female students to invest more energy and time into their studies. This suggests that the gender-differentiated impact of water access operates primarily through time-allocation shifts rather than exclusively through general health improvements (Nauges & Strand, 2017; Njoh et al., 2018; Santiago Ortiz-Correa et al., 2016; and WHO & UNICEF, 2023a).

Interestingly, while improved sanitation significantly bolsters academic performance for both genders, the lack of a significant gender interaction indicates that these benefits are largely gender-neutral. Unlike water access, which may alleviate gender-specific domestic burdens, sanitation facilities appear to be utilized equally and do not directly redistribute gendered time responsibilities. Instead, the impact of improved sanitation likely operates through shared health channels, such as reducing community-wide exposure to fecal contamination and waterborne pathogens that affect boys and girls similarly.

This result is consistent with empirical evidence from other contexts, for instance, research by Orgill-Meyer (2020) in India and other mixed-gender school settings has similarly found limited evidence of gender-disaggregated academic returns from sanitation improvements alone. Similarly, Gillani (2021) reported that improved school sanitation was associated with better educational outcomes, particularly in girls-only schools, although the effect was not statistically significant in mixed-gender schools. Together, these findings suggest limited evidence of gender-differentiated academic returns from sanitation improvements when both genders are included in the analysis. From a health perspective, limited sanitation access is associated with a higher likelihood of open defecation and open urination, which increases exposure to waterborne diseases such as diarrhea and, in turn, leads to higher student absenteeism among both boys and girls (Komarulzaman et al., 2019; Vijayalakshmi et al., 2023; and Yamauchi et al., 2022). Although inadequate sanitation can pose additional challenges for female students, particularly related to menstrual hygiene management, privacy, and the availability of disposal facilities, these constraints do not lead to statistically significant differences in academic performance across genders in this study (Phillips-Howard et al., 2016).

The findings of this study indicate that while improved water access generally correlates with positive academic outcomes, this study observes certain unexpected results, notably the statistically insignificant impact of improved water on the Mathematics and English scores of male students. These inconsistencies align with previous findings by Setyari et al. (2022), where piped water access occasionally demonstrated negligible or even negative effects. Such variations likely stem from fluctuations in water quality and quantity, which are indispensable for realizing the full human capital benefits of WASH infrastructure.

Although the current analysis utilizes WHO and UNICEF standards to classify "improved" access, the dataset lacks granular details regarding the biological safety or reliability of the water supply. In the Indonesian context, fecal contamination of improved sources remains a prevalent issue, often exacerbated by the practice of utilizing multiple water sources (MWSU), which increases exposure to pathogens such as *Escherichia coli* (Elliott et al., 2019; and Vedachalam et al., 2017). Consequently, reported access to improved infrastructure does not inherently guarantee water safety; if the water is contaminated, the anticipated health and cognitive benefits may not materialize. Furthermore, the transition from improved health to enhanced cognitive ability often involves a significant developmental lag, meaning the long-term academic returns of early-life WASH improvements may not be fully captured in contemporaneous test scores (Setyari et al., 2022).

A primary limitation of this study is the inability to account for dynamic changes in water access between the student's examination year and the most recent survey wave. However, robustness checks provided in

the Appendix (Table B) suggest that a temporal gap of one to two years does not significantly bias the primary estimates. Despite these constraints, the longitudinal nature of the IFLS dataset provides a robust foundation for identifying these broad associations over an extended period. To provide more conclusive evidence, future research should integrate objective measures of water quality (e.g., microbial testing) and precise consumption data. Additionally, incorporating variables related to menstrual health management, specific incidences of waterborne illness, and associated school absenteeism would clarify the mechanisms through which WASH impacts female students specifically. Gathering longitudinal data on these specific health shocks would allow for a more comprehensive understanding of the causal chain between infrastructure, physical health, and academic achievement across genders. Finally, tracking long-term health trajectories alongside cognitive milestones is necessary to fully grasp the potential of WASH investments in fostering human capital development in emerging economies like Indonesia.

4. CONCLUSIONS

This study investigated the association between access to improved water and sanitation and the academic performance of students in Indonesia, utilizing national examination (UN/EBTANAS) scores with a specific focus on gender-based heterogeneities. The empirical results demonstrate that access to improved Water, Sanitation, and Hygiene (WASH) infrastructure is positively and significantly associated with academic achievement across multiple subjects. These findings suggest that the quality of a student's domestic environment is a critical determinant of their educational success. A key contribution of this research is the identification of gender-differentiated impacts. The results indicate that improved water access has a disproportionately stronger positive association with the academic performance of female students. Conversely, the benefits of improved sanitation appear to be gender-neutral, positively influencing both male and female students without statistically significant differences between the two groups. These divergent findings imply that various components of WASH infrastructure influence learning outcomes through distinct socio-biological and economic pathways, most notably through time-allocation shifts for females in the case of water access and through shared health-related channels in the case of sanitation.

From a policy perspective, these findings underscore the necessity of prioritizing public investments in reliable water infrastructure, particularly within schools and residential areas, as a strategic tool to enhance overall academic performance and narrow gender disparities in education. While ongoing improvements in sanitation remain vital for student health and holistic learning, expanding access to high-quality water sources may yield more substantial educational gains for female students by alleviating domestic time burdens. Finally, while this study provides robust evidence of these associations using a comprehensive longitudinal dataset, future research should aim to further validate these relationships. Utilizing alternative educational metrics, objective water quality testing, and even richer longitudinal data will be essential to fully decipher the long-term impacts of WASH access on human capital development in emerging economies.

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Appendix A

Table A. Estimation Results by Gender

Variables	Female			Male		
	unMTH	unIND	unENG	unMTH	unIND	unENG
Water (1=improved; 0=unimproved)	0.353*** (3.42)	0.303*** (3.96)	0.189* (1.49)	0.027 (0.30)	0.195*** (2.50)	-0.075 (-0.54)
Sanitation (1=improved; 0=unimproved)	0.193*** (4.22)	0.162*** (5.31)	0.167*** (3.29)	0.135*** (3.07)	0.176*** (5.87)	0.190*** (3.84)
Electricity (1=has electricity; 0=does not have electricity)	0.170** (2.24)	0.196*** (3.53)	0.161* (1.51)	0.214*** (2.95)	0.192*** (3.62)	0.128* (1.33)
Year differences						
0 year – base						
1 year	0.056 (0.87)	-0.144*** (-3.18)	-0.027 (-0.36)	-0.096 (-1.51)	-0.075* (-1.66)	0.088 (1.13)
2 years	0.114* (1.74)	-0.071* (-1.68)	0.041 (0.56)	0.036 (0.57)	-0.056 (-1.30)	0.087 (1.16)
3 years	0.470*** (7.01)	0.198*** (4.69)	0.460*** (6.44)	0.344*** (5.35)	0.183*** (4.36)	0.509*** (7.07)
4 years	0.886 (12.24)	0.251*** (4.66)	0.679*** (7.62)	0.648*** (9.30)	0.112** (2.15)	0.687*** (8.14)
5 years	1.204*** (15.36)	0.417*** (7.77)	0.745*** (9.45)	1.020*** (14.10)	0.438*** (8.76)	0.823*** (11.28)
6 years	0.995*** (11.20)	0.499*** (8.51)	0.798*** (9.66)	0.726*** (9.00)	0.532*** (9.67)	0.789*** (9.99)
School level						
primary school – base						
junior high school	-0.459*** (-10.69)	-0.388*** (-12.67)	-0.208* (-1.75)	-0.463*** (-11.18)	-0.408*** (14.07)	-0.504*** (-6.23)
Senior high school	-1.024*** (-15.65)	-0.697*** (-17.91)	-0.443*** (-3.57)	-0.928*** (-14.73)	-0.656*** (-17.26)	-0.639*** (-7.32)
Mother's yos	0.019*** (4.04)	0.017*** (5.43)	0.033*** (6.36)	0.020*** (4.13)	0.017*** (5.67)	0.015*** (2.89)
Siblings	0.059*** (3.18)	-0.028** (-2.26)	0.033 (1.63)	-0.0004 (-0.02)	-0.036*** (-3.27)	0.030* (1.66)
Hhsize	-0.055*** (-3.06)	-0.003 (-0.29)	-0.039** (-2.06)	0.015 (0.94)	0.026** (2.36)	0.010 (0.62)
Inpce	0.454*** (18.42)	0.235*** (15.14)	0.462*** (15.84)	0.493*** (21.27)	0.238*** (15.87)	0.565*** (21.55)
Rural (1=rural; 0=urban)	0.029 (0.67)	-0.134*** (-4.54)	-0.153*** (-3.12)	-0.064 (-1.52)	-0.106*** (-3.66)	-0.160*** (-3.31)
Constant	0.095 (0.30)	3.803*** (17.84)	-0.006 (-0.02)	-0.246 (-0.81)	3.464*** (16.50)	-1.018*** (-2.70)
Observations (N)	7,199	7,416	4,690	7,498	7,754	4,787
R ²	0.175	0.141	0.173	0.174	0.133	0.196

Note: The t-statistic values for this model are indicated in parentheses. A one-tailed T-test is used for the variables improved water, improved sanitation, access to electricity, and mother's years of schooling, while a two-tailed t-test is applied to the other variables. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. An F-test confirms that all independent and control variables are collectively significant at the 1% level.

Source: IFLS 1 – 5, processed

Appendix B

Table B. Estimation Results with the Full Sample

Variables	Without Interaction			With Interaction		
	unMTH	unIND	unENG	unMTH	unIND	unENG
Water (1= improved; 0=unimproved)	0.188*** (2.69)	0.248*** (4.53)	0.062 (0.66)	0.057 (0.62)	0.192*** (2.48)	-0.073 (-0.52)
Sanitation (1= improved; 0=unimproved)	0.163*** (5.15)	0.168*** (7.83)	0.176*** (4.98)	0.170*** (4.08)	0.171*** (5.94)	0.202*** (4.26)
Electricity (1= has electricity; 0=does not have electricity)	0.198*** (3.78)	0.194*** (5.05)	0.147** (2.06)	0.199*** (3.79)	0.194*** (5.06)	0.146** (2.04)
Year differences						
0 year – base						
1 year	-0.019 (-0.42)	-0.108*** (-3.37)	0.033 (0.62)	-0.019 (-0.42)	-0.108*** (-3.36)	0.033 (0.61)
2 years	0.074 (1.63)	-0.063** (-2.10)	0.067 (1.27)	0.074 (1.63)	-0.063** (-2.09)	0.066 (1.26)
3 years	0.407*** (8.76)	0.190*** (6.34)	0.482*** (9.51)	0.407*** (8.76)	0.190*** (6.34)	0.482*** (9.51)
4 years	0.764*** (15.23)	0.179*** (4.77)	0.686*** (11.21)	0.764*** (15.23)	0.179*** (4.77)	0.685*** (11.19)
5 years	1.110*** (20.86)	0.429*** (11.67)	0.786*** (14.63)	1.109*** (20.83)	0.428*** (11.65)	0.785*** (14.62)
6 years	0.860*** (14.36)	0.516*** (12.83)	0.798*** (14.00)	0.859*** (14.35)	0.516*** (12.82)	0.797*** (13.98)
School level						
primary school – base						
junior high school	-0.462*** (-15.49)	-0.398*** (-18.65)	-0.366*** (-5.18)	-0.461*** (-15.46)	-0.398*** (-18.64)	-0.365*** (-5.17)
Senior high school	-0.979*** (-21.56)	-0.676*** (-24.58)	-0.550*** (-7.37)	-0.978*** (-21.54)	-0.676*** (-24.57)	-0.549*** (-7.36)
Mother's yos	0.019*** (5.72)	0.017*** (7.59)	0.024*** (6.55)	0.019*** (5.72)	0.017*** (7.59)	0.024 (6.56)
Siblings	0.029** (2.27)	-0.032*** (-3.80)	0.031** (2.27)	0.029** (2.28)	-0.032*** (-3.79)	0.031** (2.28)
hhsze	-0.018 (-1.52)	0.011 (1.47)	-0.013 (-1.05)	-0.018 (-1.54)	0.011 (1.46)	-0.013 (-1.05)
lnpce	0.474*** (28.06)	0.237*** (21.54)	0.514*** (26.13)	0.474*** (28.06)	0.237*** (21.54)	0.514*** (26.15)
Rural (1= rural; 0= urban)	-0.018 (-0.60)	-0.120*** (-5.76)	-0.157 (-4.58)	-0.018 (-0.59)	-0.120*** (-5.76)	-0.157*** (-4.55)
Female (1= female; 0= male)	0.079*** (2.85)	0.246*** (12.90)	0.084*** (2.68)	-0.166 (-1.25)	0.143 (1.35)	-0.129 (-0.70)
Water*female	-	-	-	0.262* (1.91)	0.110 (1.02)	0.251 (1.34)
Sanitation*female	-	-	-	-0.014 (-0.25)	-0.005 (-0.15)	-0.050 (-0.79)
Constant	-0.134 (-0.61)	3.504*** (23.35)	-0.560** (-2.03)	-0.008 (-0.04)	3.557*** (22.31)	-0.446 (-1.51)
Observations (N)	14,697	15,170	9,477	14,697	15,170	9,477
R ²	0.173	0.143	0.183	0.173	0.143	0.183

Note: The t-statistic values for this model are indicated in parentheses. A one-tailed t-test is used for the improved water; improved sanitation; Water*female; Sanitation*female variables. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. An F-test confirms that all independent and control variables are collectively significant at the 1% level.

Source: IFLS 1 – 5, processed