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Effects of Translanguaging on Science Literacy Among High School Students

Christian Genesis Guinto
Far Eastern University, Manila, Philippines
<https://orcid.org/0009-0005-5680-3886>

ABSTRACT

This study examined the effects of translanguaging on science literacy among Grade 10 students in a multilingual Philippine classroom. Seventy-eight participants were assigned to a translanguaging instruction group (n=39), integrating Filipino and English, or a monolingual instruction group (n=39). ANCOVA results showed significantly higher post-test science literacy scores for the translanguaging group (adjusted M=37.21, SE=0.64) than the monolingual group (adjusted M=29.13, SE=0.64), $F(1,75)=79.64$, $p<.001$, partial $\eta^2=.515$, controlling for pre-test scores. No significant interaction with language proficiency emerged ($F(1,73)=0.36$, $p=.549$). Cognitive engagement also showed a significant main effect ($F(2,70)=3.26$, $p=.044$, partial $\eta^2=.085$). Findings indicate that translanguaging enhances science literacy across proficiency levels, with cognitive engagement moderating outcomes, supporting its adoption in linguistically diverse classrooms.

Keywords: cognitive engagement, language proficiency, multilingual education, science literacy, translanguaging

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INTRODUCTION

In multilingual societies such as the Philippines, students routinely navigate among Filipino, English, and various regional languages in their daily lives. Yet in many science classrooms, instruction remains firmly monolingual, typically conducted in English, perpetuating linguistic injustice by excluding and devaluing students' home languages. This monolingual mandate continues a colonial legacy that positions English as superior and marginalises indigenous and national languages, thereby undermining students' linguistic identities and cultural knowledge systems. Translanguaging, which mobilises all of a student's languages for learning, offers a transformative alternative that disrupts these inequitable practices. By allowing learners to draw on their full linguistic repertoires, translanguaging scaffolds understanding of scientific concepts, validates students' linguistic identities, challenges colonial language hierarchies, and reclaims epistemic justice in science education.

Understanding the specific language ecology of this study is essential for interpreting its findings. In the Philippines, Filipino (Tagalog-based) serves as the national language and the first language (L1) for many students, while English functions as a second language (L2) and the official medium of instruction for science and mathematics in secondary schools, despite most students having greater facility in Filipino. Regional languages, including Tagalog, Bisaya/Cebuano, and Bicolano, are actively present as home and community languages. The observed advantage of translanguaging instruction over English-only instruction was not merely unsurprising but theoretically expected: students gain epistemic access when instruction leverages their stronger linguistic foundation. This study does not claim to demonstrate a surprising causal effect; rather, it provides preliminary empirical evidence for a pedagogical approach grounded in linguistic justice that challenges the institutionalised primacy of English-medium instruction in Philippine science education.

LITERATURE REVIEW

Theoretical and Conceptual Framework

This study is grounded in translanguaging theory as articulated by García and Wei (2014), which conceptualises bilingualism and multilingualism not as rigid,

compartmentalised linguistic systems but as dynamic, fluid practices wherein multilingual individuals draw upon their entire linguistic repertoire to make meaning. Otheguy, García, and Reid (2015) clarify that translanguaging refers to the deployment of a speaker's full idiolect, distinguishing it theoretically from simple code-switching. García and Wei (2014) characterise translanguaging as a fundamental reconceptualisation of how languages function in educational spaces. Wei (2018) elaborated the notion of translanguaging space as a transformative zone where multilingual learners critically reflect on their social circumstances and develop new identities. García, Johnson, and Seltzer (2017) operationalised these principles into a classroom framework organised around a translanguaging stance, design, and shifts. Cenoz and Gorter (2020) further developed pedagogical translanguaging as a planned and principled approach through which educators systematically draw on learners' full linguistic repertoires to support content learning in English-medium instruction contexts.

In science education, translanguaging theory posits that students can leverage their full linguistic resources not merely for comprehension but for higher-order scientific practices, including constructing arguments, generating hypotheses, and developing explanations (García & Wei, 2014). This approach aligns with sociocultural theories emphasising language as a mediating tool for cognitive development (Vygotsky, 1978) and positions language diversity as an intellectual resource. Complementing this, Cummins' (1979) Linguistic Interdependence Hypothesis proposes that competence developed in a learner's first language transfers positively to the second language. Cummins (2021) has since reaffirmed that multilingual pedagogies grounded in this hypothesis represent the most empirically defensible approaches to educating learners whose home languages differ from the medium of instruction.

The conceptual framework further integrates principles of culturally sustaining pedagogy and linguistic justice. Translanguaging in this context is understood not simply as a neutral instructional strategy but as a form of resistance to linguistic hegemony (the ideological privileging of dominant languages that racialises and marginalises multilingual speakers; Flores & Rosa, 2015; Rosa & Flores, 2017) and a mechanism for affirming students' cultural and linguistic identities within science learning spaces. By validating students' home languages as legitimate tools for scientific sense-making, translanguaging pedagogy disrupts deficit narratives and repositions multilingual learners as possessing valuable epistemic resources.

Empirical Evidence in Science Education

Empirical research increasingly supports translanguaging as an effective pedagogical approach in science education. A systematic review by Hou et al. (2025) synthesised findings from global K-12 science settings and identified specific translanguaging practices, including negotiating meaning in multiple

languages, using multimodal representations, and purposefully incorporating home languages, as contributing to more inclusive science classrooms and supporting scientific sense-making. González-Howard et al. (2023) argued that adopting a translanguaging lens is essential for recognising the sophistication of multilingual learners' scientific sense-making. Karlsson, Nygård Larsson, and Jakobsson (2019) found that students in Swedish science classrooms strategically used home languages to contextualise scientific content. Lu and So (2023) documented that translanguaging was most effective when teachers deliberately planned language moves aligned with specific cognitive and epistemic goals. Charamba and Zano (2019) found that Grade 10 chemistry students in South Africa who received a translanguaging intervention substantially outperformed a monolingual control group. Charamba (2023) further documented how translanguaging enabled students to gain epistemic access to scientific concepts by drawing on their full linguistic repertoires.

Translanguaging in the Philippine Educational Context

In the Philippine context, where multilingualism is the norm yet English-medium instruction persists as policy in science, research reveals both translanguaging's promise and the institutional barriers constraining its implementation. The Mother Tongue-Based Multilingual Education (MTB-MLE) policy introduced in 2012 represented a significant shift toward home languages in early schooling; however, secondary science instruction from Grade 7 onward continues to be mandated in English (Tupas & Martin, 2017). Macawile and Plata (2022) found that educators recognised translanguaging as valuable for knowledge construction while documenting significant barriers, including prevailing monolingual ideologies, standardised assessments conducted exclusively in English, and institutional policies discouraging home language use. Canilao and De Los Reyes (2023) positioned translanguaging as a matter of language rights and educational justice in the Philippine context. Familgan and Adriano (2026) documented cognitive-conceptual, affective-social, communicative, and equity-based translanguaging affordances in multilingual secondary classes in Mindanao, while also identifying challenges of linguistic leniency and learner variability. Bravo-Sotelo (2026) examined how online learning environments in the Philippines simultaneously afford and constrain students' translanguaging practices in mathematics.

Research Gaps and Study Rationale

Despite growing evidence, critical gaps remain. First, much existing research relies on qualitative methods, and few studies employ rigorous quasi-experimental designs to measure science literacy outcomes. As Grapin, Ramos Borrego, and Navarro (2025) noted, experimental outcome studies remain scarce, particularly outside of North American and European contexts. A meta-synthesis of

translanguaging in U.S. K-12 STEM contexts (Ramos, 2026) confirmed that experimental outcome studies represent a critical gap. Second, the interaction between translanguaging and individual difference variables such as language proficiency and cognitive engagement remains underexplored. Lee (2021) argued for asset-oriented framing in science and language research with multilingual learners. Third, institutional and policy constraints continue to marginalise translanguaging. As Macawile and Plata (2022) documented, monolingual assessment systems create structural barriers that limit their scalability. This study addresses these gaps by examining: (1) whether translanguaging instruction significantly improves science literacy scores compared to monolingual instruction, after controlling for pre-test performance; (2) whether effectiveness differs according to students' language proficiency levels; and (3) whether cognitive engagement and language support further influence outcomes beyond the instructional method and proficiency levels.

RESEARCH METHOD

Research Design

This study employed a quasi-experimental research design to evaluate the impact of translanguaging on science literacy among Grade 10 students during the 2024–2025 academic year. Because random assignment was not feasible within the school's organisational structure, a non-equivalent control group design was used. Two intact Grade 10 classes were purposively selected from a public secondary school (pseudonymised as ABC High School): one class served as the experimental group receiving translanguaging instruction, while the other served as the control group receiving monolingual instruction in English. A critical methodological limitation must be acknowledged: treatment assignment occurred at the class level across only two clusters, meaning standard ANCOVA F-tests may produce anti-conservative test statistics. Findings should therefore be interpreted with appropriate caution, and replication with larger cluster samples is essential before broader generalisation.

Setting and Participants

The study was conducted at ABC High School, a public secondary school in an urban-suburban area of Luzon, Philippines, serving approximately 1,200 students from predominantly working-class families. A total of 78 Grade 10 students participated ($n = 39$ per group). All participants had no prior formal exposure to translanguaging-based science instruction and provided assent along with parental consent. Both classes were taught by the same instructor, a science teacher with eight years of experience, to control for teacher-level effects. The experimental group included 23 females and 16 males; the control group included 21 females and 18 males. Socioeconomic status was comparable between groups.

Data Collection Procedures and Measures

Science Literacy Pre-test and Post-test. Both groups completed a 50-item multiple-choice science literacy assessment aligned with the Philippine Department of Education Grade 10 science curriculum and the scientific competency domains outlined in the PISA 2018 framework (OECD, 2019; validated by three science education specialists; Cronbach's $\alpha = .82$) at pre-test (Week 1) and post-test (Week 8) using parallel forms. Assessments were administered in English with a 60-minute limit.

Language Proficiency Self-Report. At baseline, students completed a self-reported language proficiency questionnaire in English and Filipino, rating science-specific ability across four skill areas on a 5-point Likert scale. Students were classified as Low Proficiency (score 4–9), Moderate Proficiency (10–14), or High Proficiency (15–20).

Cognitive Engagement Questionnaire. Students' cognitive engagement was measured using a four-item questionnaire (Fredricks et al., 2004) on a 5-point Likert scale assessing perceived focus, motivation, comprehension, and confidence. Students were classified into Low (WAM 1.00–3.70), Moderate (WAM 3.71–4.10), or High Engagement (WAM 4.11–5.00).

Language Support Questionnaire. A five-item language support questionnaire administered at mid-intervention (Week 4) assessed home language use, additional language classes, reading frequency, teacher encouragement, and parental assistance. Students were categorised as Low (5–9), Moderate (10–15), or High (16–21) support.

Intervention Conditions

Translanguaging Instruction (Experimental Group). Instruction was designed following principled translanguaging strategies (García & Wei, 2014; García et al., 2017; Lu & So, 2023). Key features included: (1) conceptual explanations introduced in Filipino or students' home languages before bridging to English technical terminology; (2) explicit encouragement for students to use any language during group discussions, lab activities, and question-asking; (3) multilingual visual aids and concept maps; (4) supplementary Filipino-language science articles alongside English textbooks; and (5) formative assessments allowing responses in Filipino, English, or any combination of classroom languages.

Monolingual English Instruction (Control Group). Instruction followed standard Department of Education curriculum guidelines, with English as the sole

medium of instruction for all explanations, discussions, and materials. Both groups covered the same science content, used the same core curriculum materials, and were taught by the same instructor for the same instructional time.

Data Analysis

Data were analysed using Analysis of Covariance (ANCOVA) to compare post-test science literacy scores between groups while controlling for pre-test scores. Two primary ANCOVA models were conducted: (1) examining the main effects of instructional method and language proficiency along with their interaction, with pre-test score as covariate; and (2) examining the main effects of cognitive engagement and language support along with their interaction, with pre-test score as covariate. Prior to analysis, key assumptions were evaluated: linearity of the covariate-outcome relationship was confirmed ($r = .68$); homogeneity of regression slopes was verified through non-significant covariate-group interaction terms ($p > .10$); normality of residuals was assessed via Q-Q plots and Shapiro-Wilk tests; and homogeneity of variance was confirmed via Levene’s test ($p > .05$). The critical assumption of independence of observations is violated due to class-level treatment assignment; results are reported with this caveat noted. Effect sizes are reported as partial eta-squared (η^2_p). All analyses were conducted using SPSS version 26.0, $\alpha = .05$.

RESULTS

Overall Outcomes and Primary Instructional Effect

Table 1 presents descriptive statistics indicating a pronounced advantage for translanguaging instruction. Students in the experimental group ($n = 39$) obtained higher post-test science literacy scores ($M = 37.21$, $SD = 5.22$) than students in the English-only control group ($n = 39$; $M = 29.13$, $SD = 5.53$), with a combined sample mean of 33.17 ($SD = 6.71$, $N = 78$).

Table 1
Descriptive Statistics for Post-test Scores by Instruction Type

Type of Instruction	Mean	SD	n
Control	29.13	5.531	39
Experimental	37.21	5.222	39
Total	33.17	6.714	78

Note. $n = 78$ (39 per group). Scores based on a 50-item science literacy test. SD = standard deviation.

Table 2 reports that ANCOVA controlling for pre-test scores produced a large, statistically significant effect of instruction type, $F(1, 75) = 79.64$, $p < .001$, $\eta^2_p = .515$, with an overall model $R^2 = .655$. The pre-test was a significant covariate,

$F(1, 75) = 62.65, p < .001, \eta^2_p = .455$. Given the class-level treatment assignment, p-values may be anti-conservative, and causal inference is limited. These results align with prior empirical work (García & Wei, 2014; Karlsson et al., 2019; Lu & So, 2023; Charamba & Zano, 2019; Hou et al., 2025).

Table 2

Tests of Between-Subjects Effects for Post-test Scores (Primary ANCOVA)

Source	Type III SS	df	MS	F	p	η^2_p
Corrected Model	2272.872 ^a	2	1136.436	71.148	< .001	.655
Intercept	1656.163	1	1656.163	103.686	< .001	.580
Pre-test	1000.757	1	1000.757	62.654	< .001	.455
Instruction	1272.115	1	1272.115	79.643	< .001	.515
Error	1197.961	75	15.973			
Total	89273.000	78				
Corrected Total	3470.833	77				

Note. ^a $R^2 = .655$ (Adjusted $R^2 = .646$). Dependent variable: Post-test score. Pre-test score served as a covariate. Given class-level treatment assignment (two clusters only), p-values should be interpreted with caution.

Instruction Effect Across Language Proficiency Strata

Table 3 presents post-test means by self-reported proficiency level. Experimental students with moderate proficiency averaged 37.18 (SD = 5.29) versus 29.00 (SD = 5.14) for control students with moderate proficiency. The experimental low-proficiency cell reported $M = 38.00$ but comprised a single participant, requiring cautious interpretation.

Table 3

Descriptive Statistics for Post-test Scores by Instruction Type and Language Proficiency Level

Instruction	Proficiency	Mean	SD	n
Control	Low	29.42	6.557	12
	Moderate	29.00	5.144	27
	Total	29.13	5.531	39
Experimental	Low	38.00	N/A	1
	Moderate	37.18	5.291	38
	Total	37.21	5.222	39
Total	Low	30.08	6.714	13
	Moderate	33.78	6.592	65

Instruction	Proficiency	Mean	SD	n
	Total	33.17	6.714	78

Note. SD not reported for cells where n = 1.

Table 4 shows that when language proficiency was added, instruction type remained a significant predictor, $F(1, 73) = 11.55$, $p = .001$, $\eta^2_p = .137$, whereas language proficiency did not significantly predict post-test scores, $F(1, 73) = 0.03$, $p = .866$, and the interaction was non-significant, $F(1, 73) = 0.36$, $p = .549$. These findings suggest that translanguaging benefited students across proficiency bands, supporting claims that it can provide epistemic access regardless of proficiency level (Macawile & Plata, 2022; Otheguy et al., 2015).

Table 4

Tests of Between-Subjects Effects for Post-test Scores (Instruction \times Language Proficiency ANCOVA)

Source	Type III SS	df	MS	F	p	η^2_p
Corrected Model	2296.376 ^a	4	574.094	35.684	< .001	.662
Intercept	1206.014	1	1206.014	74.961	< .001	.507
Pre-test	1022.170	1	1022.170	63.534	< .001	.465
Instruction	185.855	1	185.855	11.552	.001	.137
Language Proficiency	.463	1	.463	.029	.866	.000
Instruction \times Proficiency	5.844	1	5.844	.363	.549	.005
Error	1174.458	73	16.088			
Total	89273.000	78				
Corrected Total	3470.833	77				

Note. ^a $R^2 = .662$ (Adjusted $R^2 = .643$). Dependent variable: Post-test score. Pre-test score served as a covariate.

Cognitive Engagement, Language Support, and Their Roles

Table 5 shows that students categorised as highly engaged achieved the highest post-test means ($M = 36.54$, $SD = 4.99$, $n = 24$), with the high-engagement and moderate-support subgroup attaining $M = 37.38$ ($SD = 4.56$, $n = 21$).

Table 5

Descriptive Statistics for Post-test Scores by Cognitive Engagement Level and Language Support

Cognitive Engagement	Language Support	Mean	SD	n
Low	Low	29.00	N/A	1

Cognitive Engagement	Language Support	Mean	SD	n
Moderate	Moderate	32.15	9.045	13
	Total	31.93	8.731	14
	Low	29.83	3.371	6
	Moderate	32.00	6.154	31
	High	30.67	12.055	3
High	Total	31.58	6.222	40
	Low	30.67	4.509	3
	Moderate	37.38	4.555	21
Total	Total	36.54	4.995	24
	Low	30.00	3.333	10
	Moderate	33.77	6.775	65
	High	30.67	12.055	3
Total	Total	33.17	6.714	78

Note. SD not reported for cells where n = 1.

Table 6 reports that a two-way ANCOVA produced a significant main effect of cognitive engagement, $F(2, 70) = 3.26$, $p = .044$, $\eta^2_p = .085$, whereas the main effect of language support did not reach conventional significance, $F(2, 70) = 2.44$, $p = .094$. The engagement by language support interaction was negligible, $F(2, 70) = 0.02$, $p = .980$ ($R^2 = .454$, Adjusted $R^2 = .399$). These results indicate that cognitive engagement was a meaningful independent contributor to learning gains (Fredricks et al., 2004; Hou et al., 2025), while the coarse categorical measure of language support did not independently predict outcomes.

Table 6

Tests of Between-Subjects Effects for Post-test Scores (Cognitive Engagement \times Language Support ANCOVA)

Source	Type III SS	df	MS	F	p	η^2_p
Corrected Model	1575.262 ^a	7	225.037	8.310	< .001	.454
Intercept	1336.715	1	1336.715	49.362	< .001	.414
Pre-test	1025.240	1	1025.240	37.860	< .001	.351
Cognitive Engagement	176.469	2	88.235	3.258	.044	.085
Language Support	132.186	2	66.093	2.441	.094	.065
Engagement \times Support	1.085	2	.543	.020	.980	.001

Source	Type III SS	df	MS	F	p	η^2_p
Error	1895.571	70	27.080			
Total	89273.000	78				
Corrected Total	3470.833	77				

Note. $^aR^2 = .454$ (Adjusted $R^2 = .399$). Dependent variable: Post-test score. Pre-test score served as a covariate.

DISCUSSION & CONCLUSION

This study provides preliminary quantitative evidence that translanguaging instruction can substantially enhance science literacy among multilingual secondary students in the Philippine context, extending prior qualitative and theoretical work (García & Wei, 2014; Hou et al., 2025; Karlsson et al., 2019; Lu & So, 2023). The observed approximate 8-point post-test advantage for the translanguaging group, representing more than a one-standard-deviation gain, is noteworthy given that both groups received the same content, activities, and instructional time from the same teacher, suggesting that linguistic flexibility alone contributed meaningfully to learning outcomes.

The absence of an interaction between translanguaging and language proficiency indicates that the instructional approach benefited students across proficiency levels in this sample. This is theoretically consistent: translanguaging allows learners to access scientific concepts through their stronger linguistic resources while simultaneously developing English academic language, supporting depth of understanding beyond what monolingual instruction affords. The significant main effect of cognitive engagement underscores that translanguaging alone is insufficient; instruction must also foster higher-order thinking, inquiry, and active participation (Hou et al., 2025). The absence of a significant main effect for language support suggests that classroom-based translanguaging instruction may be a more potent factor than independent access to home-language materials.

Implications for Practice and Policy

For classroom practice, these findings suggest that science teachers in multilingual contexts should be supported in implementing principled translanguaging strategies. This does not mean abandoning English but rather strategically integrating students' home languages as resources for conceptual development and meaning-making. Professional development programmes should train educators in specific translanguaging moves, including: (1) introducing complex concepts in students' stronger language and bridging to technical English terminology; (2) creating opportunities for students to explain their thinking in

their preferred language during group work; (3) providing bilingual visual supports and reading materials; and (4) designing assessments that value multilingual competence. These recommendations align with calls for linguistic justice and culturally sustaining pedagogy (Canilao & De Los Reyes, 2023; Paris & Alim, 2017) and the professional development framework proposed by Lee, Grapin, and Haas (2023). Consistent with Cummins' (1979) interdependence hypothesis, translanguaging approaches can simultaneously support scientific literacy and L2 English development, demonstrating that linguistic inclusion and academic rigour are mutually reinforcing rather than competing goals.

Limitations and Future Directions

Several limitations must be acknowledged. Most critically, the quasi-experimental design with class-level treatment assignment across only two clusters limits causal inference, and reported p-values may be anti-conservative. Future studies should employ designs with larger numbers of clusters to permit multilevel modelling. Additionally, reliance on self-reported language proficiency rather than standardised assessments introduces potential bias. The eight-week intervention leaves questions about the durability of observed gains, and the single-school sample limits external validity. The study did not systematically document implementation fidelity. Future research should pursue cluster-randomised designs with adequate statistical power, balanced proficiency strata, mixed methods to capture implementation processes, long-term retention assessments, replication across diverse multilingual settings, and investigation of the interaction between instructional method and cognitive engagement.

In conclusion, this study provides preliminary evidence that translanguaging instruction substantially enhances science literacy among Grade 10 students in a multilingual Philippine classroom, with the advantage persisting across self-reported proficiency levels. Cognitive engagement emerged as an important independent contributor, suggesting that effective translanguaging pedagogy must combine linguistic flexibility with cognitively demanding instructional tasks. While findings must be interpreted cautiously given the design limitations, this study contributes to a growing body of evidence supporting translanguaging as an equity-oriented, culturally sustaining pedagogy that holds promise for transforming science education in multilingual contexts.

AI Usage Statement

The author used generative AI tools (Claude, Anthropic; Grammarly) to assist with language editing, formatting, and reference verification during manuscript preparation. These tools were not used to generate research content, analyse data, or draw conclusions. All ideas, interpretations, and findings are the original work of the author.

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Bio

CHRISTIAN GENESIS GUINTO, a PhD in Science Education student at Far Eastern University in Manila, Philippines, is a secondary school Science teacher at Cotta National High School in the Division of Lucena City. His research interests include curriculum innovation, classroom-based action research, and the integration of artificial intelligence and emerging technologies in science education. Email: guintochristiangenesis@gmail.com