Integrating English, Artificial Intelligence and Nature-Based Education for Orang Asli Pupils: A Mixed-Methods Evaluation of the Guardians of Our Future Programme

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ABSTRACT

Educational interventions for indigenous children frequently address language development, digital inclusion, or environmental learning as separate concerns, despite the interconnected nature of these competencies within contemporary education. This study examined *Guardians of Our Future* (GOF), an integrated educational programme that combines contextualised English-language learning, exposure to artificial intelligence (AI), and nature-based education for Orang Asli primary-school pupils in Malaysia. A mixed-methods design was employed with 62 Year 4 to Year 6 Orang Asli pupils from two primary schools in Melaka, Malaysia. Quantitative data were collected through pre- and post-intervention self-report measures assessing speaking, vocabulary, grammar, writing, and AI knowledge. Descriptive statistics and paired-samples *t*-tests were used to examine pre-to-post changes. Qualitative evidence of environmental awareness and understanding of sustainability was generated from pupils' verbal responses at the beginning of the programme, activity-based evidence during the programme, and written responses at the end of the programme. Significant pre-to-post improvements were reported across all measured English-language dimensions and AI knowledge. Qualitative findings indicated a progression from cleanliness-centred environmental conceptions towards ecological awareness, locally meaningful understandings of sustainability, and emerging environmental agency. These findings underscore the potential value of an integrated, culturally contextualised model in which local environmental knowledge provides meaningful learning content for acquiring English language, AI, and sustainability competencies.

Keywords: Orang Asli; Indigenous education; artificial intelligence literacy; English language learning; nature-based education

INTRODUCTION

Education for indigenous children is increasingly at the intersection of equity, linguistic participation, technological change, cultural continuity, and environmental sustainability. Yet these concerns are often approached through separate educational agendas. Language programmes focus on communicative or academic competence; digital interventions emphasise access and technological skills; environmental education develops ecological knowledge and pro-environmental orientations; and indigenous education scholarship calls for culturally responsive approaches that recognise community knowledge rather than treating learners' cultural resources as educational deficits. For indigenous pupils whose educational experiences traverse all of these domains simultaneously, such fragmentation can limit the relevance of educational interventions. What is required is not simply the addition of more educational content, but pedagogical models that connect contemporary competencies to the knowledge, environments, and lived experiences pupils already possess.

The intersecting issue is particularly pertinent to the Orang Asli, heterogeneous indigenous communities in Peninsular Malaysia with distinctive languages, cultural traditions, histories, and relationships with their environments. Hence, the Guardians of Our Future (GOF) programme was developed at precisely this intersection. Rather than constructing English, AI, and environmental learning as three unrelated programme components, GOF integrates them around culturally and environmentally meaningful tasks. Its three stated

pillars are English-language proficiency, AI use, and nature-based education, with the latter explicitly recognising Orang Asli's relationships with their environments. The intervention is aligned with SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), and SDG 15 (Life on Land).

The programme operationalises this integration through a sequence of contextualised activities. In *My Nature Story*, pupils use simple English to discuss images of local flora and fauna with vocabulary and phrase support from facilitators. In *Postcard from Forest: A Message from Nature,* pupils engage with creative writing to deliver an imaginary message based on nature's perspective. Meanwhile, *Eco Guardians: Speak Up for Our Community!* requires pupils to transform acquired knowledge into short collaborative English presentations. Finally, *Mapping Our Heritage* combines nature and AI as pupils' construct representations of an ideal sustainable village, explicitly connecting the activity with ecosystem documentation and sustainable communities.

The present study investigates GOF not merely as an English programme supplemented with environmental and AI activities, but as an integrated educational intervention intended to connect linguistic development, technological participation, ecological awareness, and community-relevant sustainability among Orang Asli primary pupils. The following research questions will be addressed:

RQ1) To what extent did participation in GOF improve pupils' self-reported English-language competence, specifically speaking skills, grammar knowledge, vocabulary knowledge, and writing skills, from pre-test to post-test?

RQ2) To what extent did participation in GOF improve pupils' self-reported AI knowledge from pre-test to post-test?

RQ3) How does participation in nature-based education shape pupils' environmental awareness and understanding of sustainability?

LITERATURE REVIEW

2.1 Nature-Based Education, Environmental Awareness and Sustainability

Nature-based education provides a potentially meaningful context for developing environmental awareness because it situates learning in relation to natural environments rather than treating ecological knowledge solely as abstract curricular content; however, evidence does not support the stronger assumption that exposure to nature alone necessarily produces environmental learning. Miller et al.'s (2021) systematic review of 20 quantitative studies involving primary-school-aged children found predominantly positive outcomes associated with nature-based learning, but methodological weaknesses and substantial variation across interventions limit conclusions about which pedagogical features generate particular outcomes. More compelling evidence for deliberately structured environmental education comes from van de Wetering et al.'s (2022) meta-analysis of 169 studies, 512 effect sizes, and 176,007 children and adolescents across 43 countries. Environmental education was associated with significant gains in environmental knowledge ($g = .953$), attitudes ($g = .384$), intentions ($g = .256$), and predominantly self-reported behaviour ($g = .410$), although substantial heterogeneity was evident. Crucially, the considerably stronger effect on knowledge than on intentions indicates that knowing about environmental issues cannot be assumed to translate directly into willingness or sustained capacity to act. Thus, nature-based environmental education can be conceptualised as a pedagogically mediated process through which learners may develop ecological understanding, rather than as an intrinsically effective consequence of contact with nature.

This distinction becomes particularly important in indigenous education because environmental learning does not necessarily begin with knowledge introduced through formal schooling; learners may already possess understandings derived from family, community, place, and culturally situated interactions with the natural environment. Abdul Wahab et al. (2020), for example, developed a Forest School framework from interviews with six Orang Asli community experts and identified indigenous knowledge concerning forests, herbs and medicine, handicrafts, hunting tools, and other cultural practices as potentially relevant educational resources. Although Abdul Wahab et al.'s (20220) framework-development study does not establish that incorporating such knowledge improves pupils' environmental outcomes, it challenges approaches that position indigenous

children merely as recipients of externally defined environmental knowledge. Their study shows the feasibility of nature-based education to serve as a bridge between existing place-related knowledge and formal ecological and sustainability concepts, provided that local knowledge is meaningfully incorporated rather than merely represented superficially.

All in all, existing evidence remains limited regarding how structured nature-based interventions develop environmental awareness, understanding of sustainability, and movement towards environmental responsibility among Malaysian Orang Asli primary pupils. This limitation warrants further research that examines not merely whether pupils acquire environmental knowledge, but also how their environmental reasoning develops and connects with locally meaningful understandings of sustainability.

2.2 Contextualised English Learning in a Multilingual Indigenous Setting

Contextualised English learning is particularly relevant in multilingual indigenous settings because it connects language acquisition to learners' cultural identities, lived experiences, and community knowledge, making learning more meaningful, inclusive, and responsive to their linguistic and sociocultural backgrounds. In two Orang Asli schools in Pahang, Idrus et al. (2023) found that incorporating elements such as indigenous celebrations, native language, food preparation, and traditional clothing into English lessons generated considerable pupil interest, leading the authors to question a uniform approach to English curricula for culturally diverse learners. However, because the study was a small qualitative case study involving ten pupils and four teachers, it supports claims concerning engagement and perceived cultural relevance, not causal claims that culturally contextualised instruction improves English proficiency. The multilingual dimension is strengthened by Rajendram's (2023) study of a Malaysian Grade 5 classroom, which showed that student-led translanguaging enabled learners to mobilise their linguistic repertoires for meaning-making, access to knowledge, interpersonal interaction, and identity expression, while English-only ideologies could constrain these resources. Together, these findings challenge the assumption that effective English learning necessarily requires separation from pupils' existing languages and cultural knowledge; instead, those resources can function as pedagogical scaffolds for accessing and producing English, although their contribution depends on how deliberately they are incorporated into instruction.

The evidence is, nevertheless, insufficient to conclude that contextualisation alone produces measurable development in vocabulary, grammar, speaking, and writing among Indigenous pupils. Existing Malaysian studies provide stronger support for the pedagogical appropriateness of culturally responsive and multilingual instruction than for its comparative effectiveness on specific English-language outcomes. This limitation is consequential because superficial cultural inclusion, such as by merely inserting indigenous images or vocabulary into otherwise unchanged lessons, does not necessarily constitute contextualised language pedagogy. A stronger approach requires familiar cultural, community, or environmental knowledge to provide meaningful content that enables learners to encounter and subsequently use English vocabulary and grammatical structures for genuine communication. Such an approach also avoids treating pupils' home languages as linguistic deficits while recognising that English remains the target additional language. Consequently, an important empirical gap concerns whether systematically contextualised instruction that mobilises familiar environmental and community knowledge can support productive English development among multilingual Orang Asli primary pupils, particularly when vocabulary and grammar are deliberately recycled through speaking and writing rather than taught as disconnected language components.

2.3 AI Literacy in Primary and Inclusive Education

AI literacy in primary education should not be reduced to pupils' ability or confidence in operating an AI application; contemporary scholarship conceptualises it as involving multiple dimensions of understanding, application, evaluation, data awareness, and ethical judgement. Yim and Su's (2025) systematic review identified only 25 empirical primary-school studies and organised the literature around interaction and collaboration with AI, computational thinking, critical data literacy, and AI ethics; constructivist, project-based, programming, and human–AI interaction approaches were prominent, with generally positive academic, affective, and behavioural outcomes. The small evidence base and its geographical concentration, however, constrain broad claims concerning what constitutes effective AI-literacy education across diverse primary populations. At the empirical level, Ng et al. (2022) demonstrated that 82 Hong Kong primary pupils could engage with AI concepts through

a three-month inquiry-based digital-story-writing programme, illustrating the feasibility of embedding AI learning within a meaningful interdisciplinary task rather than teaching it exclusively as technical content. Such evidence supports experiential and purposeful AI learning, but it does not justify treating practical AI use as equivalent to comprehensive AI literacy; interaction with a tool represents only one component of the broader capacity to understand, evaluate, and use AI responsibly.

This distinction is especially consequential for inclusive primary education because pupils enter AI-mediated learning with unequal linguistic resources, technological experience, access, confidence, and opportunities to use digital tools. Lee and Kwon's (2024) systematic review of 25 K–12 studies found frequent use of hands-on and project-based approaches and generally positive learning outcomes, but also emphasised the need for curricula, pedagogies, and tools responsive to particular learners and educational contexts. More critically, the existing evidence remains dominated by mainstream K–12 populations, leaving comparatively little empirical understanding of how AI literacy can be introduced appropriately to multilingual indigenous primary learners. Inclusive AI education, therefore, requires more than providing access to technology: practical interaction must be scaffolded, developmentally appropriate, linguistically accessible, and progressively connected to critical issues such as reliability, privacy, ethics, and responsible use. The resulting research gap is not simply whether Indigenous primary pupils can use AI, but how introductory AI experiences can develop knowledge and confidence without conflating tool familiarity with comprehensive AI literacy, while allowing technology to support rather than displace learners' existing cultural, linguistic, and community knowledge.

METHODS

3.1 Research Design

This study employed a mixed-methods intervention design to investigate changes associated with participation in the *Guardians of Our Future* (GOF) programme among Orang Asli upper primary-school pupils. Quantitative and qualitative evidence were collected because the programme targeted outcomes that could not be adequately captured through a single methodological approach. The quantitative strand examined changes in pupils' self-reported English-language competence and AI knowledge before and after participation in GOF, whereas the qualitative strand examined how pupils articulated their understanding of environmental responsibility and sustainability throughout the intervention.

More specifically, the quantitative component followed a one-group pretest–posttest design. The same pupils completed self-report measures at the beginning of Session 1 and at the end of Session 4, permitting within-participant comparison of scores across the intervention period. The principal quantitative outcomes were speaking skills, vocabulary knowledge, grammar knowledge, writing skills, and AI knowledge.

The qualitative component adopted a temporally comparative approach. Pupils' initial conceptions of environmental responsibility were elicited verbally at the beginning of Session 1, before the substantive programme activities, and subsequently compared with their written responses at the end of Session 4. Evidence generated through GOF's nature- and sustainability-oriented activities, particularly during *Postcard from Forest: A message from the Nature*, *Eco Guardians: Speak Up for Our Community!*, and Mapping Our Heritage, provided contextual support for interpreting this development. The programme documentation confirms that these activities respectively integrated traditional and scientific environmental knowledge, community-oriented action, and representations of sustainable villages.

3.2 Research Context, Setting and Participants

The study was conducted within the *Guardians of Our Future* programme, an educational initiative implemented by the Akademi Pengajian Bahasa, Universiti Teknologi MARA (UiTM) Cawangan Melaka. GOF was conducted face-to-face at two Orang Asli primary schools. The programme was implemented across eight instructional sessions (four sessions per school) between late May and early July 2026. The programme targeted Orang Asli pupils in Years 4–6 from the two participating schools. This educational setting was particularly relevant to GOF's objectives because the intervention was designed around three interconnected pillars: English-language proficiency, AI use, and nature-based education.

A purposive sampling technique was employed to select participants. The study comprised 62 Orang Asli pupils from Years 4, 5, and 6 (upper primary), with 31 pupils recruited from each of the two participating schools, resulting in an evenly distributed sample across the two sites.

3.3 The Guardians of Our Future Intervention

GOF comprises four instructional sessions that were conducted on four different days. Each session is organised around a principal activity and associated SDG outcomes.

Session 1: ***My Nature Story***

The first instructional session introduced contextualised English-language learning through *My Nature Story*. Pupils were given picture cards depicting local flora associated with forests, rivers, and community environments. Facilitators then provided key vocabulary and phrases to scaffold pupils' oral communication, before the pupils, in pairs, described the images in simple English. The pupils were also encouraged to contribute local names or knowledge of the species before facilitators introduced or confirmed the species' English and basic scientific names. Rather than merely describing and identifying the species, pupils also discussed where each plant or animal could be found, its characteristics and uses. During the pair presentation and mass discussion about plants and animals, the students jotted down notes on them. The activity was aligned with SDG 4 and was designed to improve English through an activity-based, context-rich approach. Pedagogically, this activity established an important principle underlying GOF: English was not introduced through decontextualised vocabulary lists or structurally isolated exercises. Instead, the new language was connected with environmentally familiar referents. Thus, pupils could draw on existing conceptual knowledge while acquiring additional English lexical and communicative resources.

The quantitative pretest was administered before *My Nature Story* was conducted. Meanwhile, the baseline qualitative elicitation for RQ3 was conducted at the beginning of *My Nature Story* activity as scaffolding.

Session 2: ***Postcard from the Forest: A Message from Nature***

Session 2 foregrounded nature-based education through Postcard from the Forest: A Message from Nature, a creative writing activity in which pupils imagined that a familiar element of nature, such as a tree, river, plant, bird, fish, butterfly, or other local animal, could communicate with humans. Building slightly on the descriptive foundation established through My Nature Story, the activity moved pupils beyond simply writing about nature to writing from nature's perspective. This activity aimed to provide a refreshing writing challenge while retaining GOF's emphasis on pupils' relationships with their natural and community environments.

The activity began with guided language building. Rather than teaching grammar as an isolated component, facilitators introduced grammatical structures as functional language resources that pupils could apply directly to their environmental writing. Pupils first used the simple present to describe the characteristics, habitats, and functions of plants and animals, as illustrated in sentences such as “I live in the forest” and “Animals live in my branches.” They then extended these descriptions by using because to explain environmental relationships and significance, for example, “I am important because animals need me.” Simple conditional structures were subsequently introduced to help the pupils’ express relationships between human actions and environmental consequences, as in “If people cut too many trees, animals lose their homes.” Finally, modal verbs such as should, must, and can enabled pupils to communicate environmental responsibility and possible actions, for example, “People should protect the forest.”

The central task was to create a “Postcard from Nature.” Each pupil selected a natural element and imagined receiving a postcard written from that element's perspective. The postcard contained four short sections: Who am I? → Why am I important? → What is happening around me? → What would I like people to remember? Pupils could illustrate the front of the postcard and complete the written message on the reverse. For example, a pupil who chose a tree might write:

Hello! I am an old forest tree.

Birds and insects live near me. My branches give animals a place to rest. I am useful to the forest. If too many trees are cut down, some animals will lose their homes. Please take care of our forest.

From: Your Forest Tree

Completed postcards were later displayed around the learning space. Pupils later walked around, read several classmates' postcards, and placed a small sticker beside one message that taught them something new about nature. They can then add one short written response, such as "I will keep your water clean", "I will protect your home", or "I learned that fish need clean water."

Session 3: *Eco-Guardians: Speak Up for Our Community!*

Session 3, *Eco-Guardians: Speak Up for Our Community!*, is a collaborative speaking challenge in which pupils use English to propose solutions to environmental issues affecting a fictionalised community environment. Small groups receive an illustrated Eco-Challenge Card presenting an age-appropriate environmental problem, such as*: Rubbish is entering the river; Too many trees are being cut down; Animals are losing places to live; The village has too much rubbish;* or *Useful plants are disappearing*. The visual scenarios are particularly suitable for upper-primary pupils because they make the communication task concrete while providing sufficient scope for problem solving, collaboration, and environmental reasoning. Each group first identifies the problem and discusses why it matters before developing a simple Community Action Plan containing three elements: What is the problem? Why does it matter? What can we do about it?

Before the group presentations, facilitators explicitly scaffold the vocabulary and grammatical resources required for successful oral communication. Pupils revisit environmental vocabulary acquired during the preceding activities, including *river, forest, habitat, rubbish, pollution, animals, plants, clean, protect, save, destroy, recycle,* and *plant*. They then practise functional sentence frames such as "The problem is …," "This is important because …," "We should …," "We should not …," "If we …, then …," "Our group wants to …," and "We can help by …." Particular attention is given to modal verbs (*can, should, must*), imperatives, simple present structures, and basic cause-and-effect language. The scaffolding enables less-proficient pupils to participate while allowing more proficient pupils to expand their ideas independently.

Each group subsequently delivers a two- to three-minute Eco-Guardian Pitch to classmates and facilitators. Groups may create a simple poster containing a campaign name and three key actions, such as "Save Our River," "Protect Our Forest," or "Keep Our Kampung Green." After each presentation, the audience asks one simple question, such as *"Why should we protect the river?"* or *"How can children help?"*, requiring presenters to respond spontaneously using the vocabulary and grammatical structures practised during the session. The activity can conclude with pupils voting on an action they believe their community could realistically undertake, adding an element of authentic decision-making without turning the activity into a competition primarily based on English proficiency.

Session 4: *Mapping Our Heritage*

The final instructional session integrated nature and AI through *Mapping Our Heritage*. Pupils constructed a "map" representing their ideal sustainable village and included environmental and community features they considered desirable. The activity was aligned with SDG 15 through ecosystem documentation and SDG 11 through sustainable human settlements. Conceptually, *Mapping Our Heritage* served as the culminating integrative activity because it required pupils to translate environmental and sustainability ideas into a locally meaningful representation. Rather than approaching sustainability exclusively as an abstract definition, pupils considered what sustainability could mean within a community environment they could visualise.

The programme concluded with the quantitative post-test that took place after *Mapping Our Heritage* activity ended.

3.4 Research Instruments

A pre- and post-intervention self-report questionnaire was used as the main instrument in this study. The

questionnaire was designed to capture changes in pupils' perceptions of their English-language competence (specifically in terms of speaking skills, writing skills, vocabulary knowledge and grammar knowledge) and AI knowledge, as well as their perceptions on sustainability.

The questionnaire that consists of twenty-seven 4-point Likert-type scale items to answer RQ1 and RQ2, and 1 subjective question to answer RQ3 was checked for face and content validity by two experts in Teaching English as a Second Language prior to its administration in this study. The 4-point Likert-type scale items in the questionnaire require the pupils to respond on these options: *Strongly Agree, Agree, Disagree,* and *Strongly Disagree*. The use of an even-numbered response scale, 4-point Likert-type scale items was to remove a neutral midpoint, requiring pupils to indicate either agreement or disagreement with each statement.

Out of 27 items, 5 items each were addressed on speaking skill, writing skill, vocabulary knowledge, and grammar knowledge, while remaining 7 items were addressed on AI knowledge. Meanwhile, the sole subjective question in the questionnaire, "What can you do to protect nature and make your village continue to be a good place to live in the future?" was aimed to collect students' qualitative responses on their environmental awareness and understanding of sustainability after attending the programme. The subjective question was only included in the post-intervention questionnaire that consisted of Likert-type scale items whereas the pre-intervention questionnaire consisted of Likert-type scale items only.

3.5 Data Collection and Data Analysis

The questionnaire was administered on two occasions: once at the beginning of Session 1, before the *My Nature Story* activity began, and again at the end of Session 4, after the *Mapping Our Heritage* activity had ended. Completion of the questionnaire required approximately 7 minutes each time. The resulting dataset was subsequently entered into SPSS, where means, standard deviations, and paired-samples *t*-tests were calculated to answer RQ1 and RQ2.

RQ3 examined pupils' environmental awareness and understanding of sustainability qualitatively before and after their participation in the GOF programme. To capture students' development in these areas, qualitative data were collected at different stages of the programme using three complementary sources: pre-intervention verbal responses; artefacts and pupil explanations generated during the *Mapping Our Heritage* activity; and post-intervention written responses. Collecting evidence at different points enabled the researchers to compare pupils' initial conceptions of environmental responsibility with the more developed ideas they expressed after participating in the nature-based learning activities.

At the beginning of Session 1, before the substantive GOF activities commenced, the researchers conducted a brief whole-group oral elicitation to establish pupils' initial understanding of environmental responsibility. The questions were intentionally phrased in simple, age-appropriate language, including: "What should we do to take care of our village and nature?", "How can we take care of the river?", and "What should people not do to the forest or river?" Pupils were encouraged to respond spontaneously using simple English, Malay, or a combination of languages. Allowing multilingual responses was important because RQ3 aimed to investigate pupils' environmental understanding rather than their English proficiency. Restricting responses to English may have underestimated the environmental knowledge of pupils who understood the concepts but did not yet have sufficient English proficiency to express them fully. The researchers recorded the responses in structured field notes, paying particular attention to the environmental actions, responsibilities, and relationships expressed by the pupils. These responses constituted the pre-intervention baseline against which subsequent evidence of students' development in environmental awareness and understanding of sustainability would be compared.

Additional qualitative evidence was generated during Session 4 of *Mapping Our Heritage.* During this activity, pupils constructed representations of an ideal sustainable village and explained the environmental features included in their maps. The researchers examined both the artefacts and pupils' accompanying explanations, focusing on how they represented environmental protection and sustainability through features such as clean surroundings, rivers, forests, plants, animals, and responsible community practices. The maps were interpreted together with pupils' explanations rather than as isolated visual products. At the end of Session 4, a final source of qualitative evidence was obtained through a short subjective item incorporated into the post-test questionnaire, which asked pupils what they could do to protect nature and ensure that their village remained a good place to

live in the future. Together, these three sources provided evidence across the programme trajectory: what pupils initially understood and could articulate, how they represented sustainability during the culminating activity, and how they subsequently explained environmental responsibility in writing.

The three sources of qualitative evidence were analysed using an inductive–deductive thematic analysis. The analysis was designed to identify both recurring ideas emerging directly from pupils' responses and broader patterns relevant to the study's focus on environmental awareness, sustainability, and responsibility. Importantly, the researchers did not treat longer or more linguistically sophisticated responses as automatic evidence of stronger environmental understanding. Instead, attention was directed primarily to the environmental meaning contained in each response, particularly the range of environmental issues recognised, the relationships pupils established between human actions and ecological consequences, and the extent to which they expressed responsibility or proposed environmental action.

FINDINGS AND DISCUSSION

Research Question 1: To what extent did participation in GOF improve pupils' self-reported English language competence, specifically in speaking skills, grammar knowledge, vocabulary knowledge, and writing skills from pre-test to post-test?

Construct	Pre-Test	Post-Test	Mean Gain	t (61)	p	d_z (Magnitude)
	Mean (SD)	Mean (SD)				
Speaking	2.48 (0.803)	3.38 (0.720)	0.9	7.47	<.001	0.96 (Large)
Vocabulary	2.60 (0.751)	3.44 (0.687)	0.84	7.42	<.001	0.95 (Large)
Grammar	2.44 (0.822)	3.25 (0.756)	0.81	6.52	<.001	0.84 (Large)
Writing	2.42 (0.894)	3.30 (0.802)	0.88	6.57	<.001	0.85 (Large)

Statistically significant pre-to-post improvements were observed across all English-language outcomes, indicating GOF effective\ess.

Speaking demonstrated a substantial improvement following participation in GOF, increasing from M = 2.48 (SD = 0.803) at pre-test to M = 3.38 (SD = 0.720) at post-test, $t(61) = 7.47$, $p < .001$, with a large effect size (d_z== .96). Among the four English-language outcomes, speaking recorded both the largest mean gain (0.90) and the largest effect size, suggesting that pupils experienced particularly marked improvement in their perceived ability and confidence to communicate orally in English. The visible improvement can be attributed to the communicative and activity-based structure of GOF, in which pupils repeatedly used English to describe, discuss, and present ideas concerning familiar environmental content such as plants, animals, rivers, forests, and their community. Rather than requiring pupils to generate ideas about unfamiliar topics while simultaneously managing an additional language, GOF provided recognisable content around which English communication could be organised, potentially reducing the conceptual demands of oral participation and allowing greater attention to linguistic expression.

Moreover, collaborative and task-oriented activities created opportunities for meaningful language use rather than restricting speaking practice to decontextualised drills. This interpretation is supported by Yu et al.'s (2024) systematic review, which found that task-based language teaching generally enhanced EFL speaking proficiency while supporting engagement, motivation, linguistic development, and willingness to use the target language. Recent Malaysian evidence provides a more qualified comparison: Abd Rahman (2024) found that task-based instruction supported development in spoken production, interaction, fluency, and engagement among Malaysian ESL learners.

Vocabulary knowledge similarly showed substantial improvement, increasing from M = 2.60 (SD = 0.751) to M

= 3.44 (SD = 0.687), t(61) = 7.42, p < .001, with a large effect size (d_z = .95). The magnitude of this change, which closely approximated that observed for speaking, appears consistent with the way vocabulary was embedded throughout GOF. English lexical forms were repeatedly connected to concrete, contextually meaningful referents, including plants, animals, rivers, forests, nature, and village activities, rather than being introduced predominantly as isolated words. Such contextualisation may have facilitated the formation of connections among lexical forms, meanings, visual or physical referents, and pupils' existing conceptual knowledge. In the GOF context, this mechanism is particularly important because pupils did not necessarily need to acquire an unfamiliar concept and its English label simultaneously; where environmental referents were already familiar, learning could instead involve connecting existing conceptual knowledge with an additional English lexical form. In addition, previous research in the Malaysian ESL context has shown that contextualised vocabulary instruction can contribute to vocabulary development and related language performance (see Subon & Unin's, 2021).

Grammar knowledge also improved significantly, from M = 2.44 (SD = 0.822) at pre-test to M = 3.25 (SD = 0.756) at post-test, t(61) = 6.52, p < .001, with a large effect size (d_z = .84). Although grammar recorded the smallest effect among the four English-language outcomes, this relative pattern should not be interpreted as evidence that GOF was less effective in developing grammar; rather, it is consistent with the programme's instructional emphasis. GOF was principally contextual, communicative, and experiential rather than an intensive form-focused grammar intervention. Pupils encountered grammatical resources while describing plants and animals, discussing environmental activities, producing sentences, and communicating ideas. Furthermore, existing literature indicates that task-based interaction can facilitate grammatical development, but the magnitude of such development depends on task characteristics and the degree to which learners' attention is directed towards grammatical form. For example, Lee's (2023) meta-analysis of Korean EFL learners reported a significant medium effect of consciousness-raising tasks on English grammatical competence (g = .617, p < .001), providing evidence that instructional tasks designed to direct learners' attention to grammatical forms can facilitate grammar learning.

Writing skills demonstrated a statistically significant improvement following participation in GOF, increasing from M = 2.42 (SD = 0.894) at pre-test to M = 3.30 (SD = 0.802) at post-test, t(61) = 6.57, p < .001, with a large effect size (d_z = .85). This substantial pre-to-post change suggests that pupils perceived themselves as considerably more capable and confident in expressing ideas in written English after participating in the GOF programme. Although the observed effect size was marginally larger than that for grammar (d_z = .84), it was numerically lower than those for speaking (d_z= .96) and vocabulary (d_z= .95).

The substantial writing gain can be understood in relation to the contextual and knowledge-bridging structure of GOF. Pupils were not required to construct written responses around entirely unfamiliar subject matter; instead, the programme repeatedly engaged them with familiar and increasingly elaborated environmental content involving plants, animals, rivers, forests, village environments, and environmental responsibility. Such familiarity may have reduced the conceptual burden of deciding what to write, enabling pupils to direct more attention towards how those ideas could be expressed in English. The programme's strong vocabulary outcome may also be connected to gains in writing because lexical resources enable learners to translate ideas into written language (see Subon & Unin, 2021).

Research Question 2: To what extent did participation in GOF improve pupils' self-reported AI knowledge from pre-test to post-test?

Construct	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Gain	t (61)	p	d_z (Magnitude)
AI	2.28 (0.886)	3.36 (0.725)	+1.08	8.14	<.001	1.03 (Very Large)

Pupils demonstrated a substantial pre-to-post improvement in their self-reported AI knowledge and confidence following participation in GOF, with the mean increasing from M = 2.28 (SD = 0.886) to M = 3.36 (SD = 0.725), t(61) = 8.14, p < .001, representing a large effect (d_z = 1.03). The magnitude of this change is particularly notable

given the comparatively low pre-intervention mean, suggesting that pupils entered the programme with limited perceived familiarity with AI. The increase following GOF appears to reflect an important shift from limited prior exposure towards greater practical familiarity, perceived knowledge, and confidence in using AI. One rational explanation lies in the programme's emphasis on learning AI through purposeful use rather than introducing it solely as an abstract technological concept.

Pupils encountered AI within activities in which the technology supported meaningful tasks, such as organising ideas and representing environmental or community-related knowledge. This interpretation is consistent with Ng et al. (2022), who investigated an inquiry-based digital story-writing intervention involving

82 primary pupils and demonstrated the feasibility of developing AI literacy by engaging children in meaningful, interdisciplinary activities rather than teaching AI exclusively as technical content. Their study further conceptualised AI literacy as involving not only knowledge of AI but also the ability to apply and evaluate AI and consider its ethical implications. Similarly, Yim's (2024a) empirical study of primary-school pupils found statistically significant improvement in AI literacy following an arts-based, transdisciplinary intervention, with qualitative evidence indicating that constructing and reflecting on artefacts supported pupils' conceptual understanding of AI. These findings lend support to the interpretation that younger learners may develop greater understanding of AI when technological concepts are embedded within accessible, purposeful, and age-appropriate learning experiences.

The GOF finding is also important because AI literacy education at the primary level remains considerably less developed than at secondary and tertiary levels. Yim's (2024b) critical review concluded that AI-literacy education has predominantly targeted secondary-school and university learners, while frameworks specifically addressing younger pupils remain comparatively underdeveloped. The review further emphasised that age-appropriate AI education should extend beyond operational use to encompass broader dimensions of AI understanding. A more recent synthesis by Yim and Su (2025) similarly highlights the emerging nature of AI-literacy education in primary schools and the need for pedagogical approaches specifically suited to younger learners. Against this background, the substantial change observed among the GOF pupils is noteworthy, as it suggests that primary-aged Indigenous learners can meaningfully engage with AI when exposure is appropriately scaffolded and connected to activities with an identifiable purpose. Rather than positioning pupils as passive recipients of explanations about AI, GOF provided opportunities to interact with AI as a learning tool. Learning by doing is especially important for learners with limited prior exposure because practical interaction can make an otherwise abstract technology more concrete and accessible. Additionally, evidence from K–12 settings supports this interpretation: Zhang et al. (2024), in a comparison study involving 158 middle-school pupils, found that participation in a teacher-led AI-literacy curriculum improved students' AI-related learning outcomes relative to pupils who did not receive the curriculum, demonstrating that structured classroom experiences can develop AI literacy among school-aged learners.

The large change may also reflect the relationship between practical AI experience and pupils' developing confidence. The GOF AI measure did not concern factual AI knowledge alone; it also included pupils' perceived ability to use AI for tasks such as creating mind maps and organising ideas with ChatGPT, their confidence and enjoyment in using the technology, their willingness to teach others, and their intention to continue learning about AI. Consequently, the increase from 2.28 to 3.36 is better interpreted as development across a combination of perceived AI knowledge, operational familiarity, confidence, and engagement, rather than as growth in technical knowledge alone. This broader interpretation is compatible with current conceptualisations of AI competence. Chiu et al. (2024), for example, argue that AI competency should extend beyond knowledge to encompass confidence and self-reflective capacities, as well as technological, ethical, collaborative, and societal dimensions. Thus, GOF's practical AI activities may have contributed not merely to pupils knowing more about AI but also to their developing a stronger perception that they could actually use AI for meaningful purposes.

Research Question 3: How does participation in nature-based education shape pupils' environmental awareness and understanding of sustainability?

The qualitative findings revealed a discernible development in how pupils conceptualised environmental responsibility and sustainability across their participation in GOF. Comparison of the pre-intervention verbal responses with evidence generated during Mapping Our Heritage activity and the post-intervention written

responses produced three interconnected themes: (1) From General Cleanliness to Ecological Awareness, (2) Sustainability Becomes Locally Meaningful, and (3) Emerging Environmental Agency. Importantly, these themes should not be interpreted as indicating that pupils entered the programme without environmental knowledge. On the contrary, their initial responses demonstrated an existing awareness of basic environmental responsibility. What appeared to develop across the programme was the breadth, relational complexity, local relevance, and agentive orientation of their environmental reasoning. The progression involved a movement from recognising appropriate environmental behaviours towards explaining ecological relationships, connecting sustainability with the future of their own community, and identifying actions through which they and others could contribute to environmental protection.

Theme 1: From General Cleanliness to Ecological Awareness

The first theme captures a qualitative shift from an initially concrete, cleanliness-oriented conception of environmental responsibility towards a more differentiated understanding of ecological relationships. During the pre-intervention verbal elicitation in Session 1, most pupils expressed environmental responsibility primarily through immediately observable behaviours concerning rubbish, cleanliness, and pollution. Representative responses included:

"*Don't throw rubbish in the river." (Student 3)*

"We must keep our kampung clean." (Student 45)

"Cannot throw rubbish everywhere." (Student 61)

"Clean the river." (Student 17)

"Don't make the forest dirty." (Student 29)

These statements are significant because they demonstrate that pupils were not environmentally unaware before GOF. They already possessed an elementary normative understanding of environmental responsibility: littering was undesirable, rivers should remain clean, and the village and forest should be cared for. However, their initial reasoning was predominantly behavioural and rule oriented. The responses identified what people should or should not do, but generally did not elaborate on the ecological consequences of those behaviours or the relationships among human activities, organisms, habitats, and environmental conditions. Environmental responsibility was expressed mainly as maintaining cleanliness rather than as understanding an interconnected ecological system.

By Session 4, pupils' explanations during Mapping Our Heritage and their post-intervention written responses reflected a broader environmental repertoire. Their statements increasingly incorporated habitats, plants, animals, rivers, human needs, future resource availability, and relationships between human actions and ecological consequences. Among the examples are:

"We must protect the forest because animals live there." (Student 58)

"We should keep the river clean so the fish can live and people can use clean water." (Student 17)

"Do not cut all the trees because animals need the forest." (Student 14)

"We must take care of useful plants, so they are still there in the future."(Student 22)

"We should protect plants and animals, not only clean the rubbish." (Student 53)

"If people throw rubbish in the river, the water becomes dirty and fish can die." (Student 9)

"We need many kinds of plants and animals because they are important for nature." (Student 16)

These later responses differ qualitatively from the initial statements because pupils increasingly supplied an ecological rationale for environmental action. Student 3 provides a particularly illustrative example. The initial

statement, “Don't throw rubbish in the river,” identifies an appropriate behaviors, whereas the later statement, “If people throw rubbish in the river, the water becomes dirty and fish can die,” constructs a causal relationship between human action and environmental degradation. Similarly, Student 14's statement links tree conservation to habitat availability, while Student 17 connects river quality to aquatic life and human water use. Student 22 extends the reasoning temporally by relating plant conservation to future availability. Taken together, these responses indicate a shift from knowing environmental rules to beginning to understand why environmental protection matters within an interconnected ecological system. This pattern is also consistent with broader empirical evidence concerning environmental education among children and adolescents by Van de Wetering et al. (2022).

Aside from that, the nature-based and place-responsive characteristics of GOF provide a plausible pedagogical explanation for this development. Pupils encountered environmental relationships through rivers, forests, plants, animals, and community environments rather than primarily through distant or generic environmental examples. This is consistent with the conceptual foundation of place-based education, which connects teaching and learning to the physical, ecological, cultural, and community contexts in which learners are situated. In their systematic review of 149 studies, Yemini et al. (2025) found that environmental studies constituted the largest subject-specific strand of place-based education research and that improving environmental awareness was among the most frequently identified intended outcomes. They characterise place-based education as emphasising experiential, community-based, contextual, and ecological learning that strengthens connections with local environments and cultures. GOF extends this logic to an Orang Asli educational context: rather than introducing environmental responsibility solely through abstract sustainability discourse, the programme provides opportunities for pupils to reason ecologically through environmental features they can meaningfully engage with. The significance of Theme 1 lies not simply in pupils knowing more environmental terms, but in their increasingly relational conception of environmental responsibility, in which human behaviour is understood in relation to river health, habitats, plants, animals, biodiversity, and future environmental conditions.

Theme 2: Sustainability Becomes Locally Meaningful

The second theme concerns the localisation of sustainability. Analysis of the *Mapping Our Heritage* artefacts and pupils' accompanying explanations suggested that sustainability was rarely represented as an abstract or technical concept. Instead, pupils translated it into recognisable characteristics of a desirable community environment. Recurring features included clean rivers, protected forest areas, trees around houses, spaces for animals, conservation of useful plants, clean communal areas, and human practices that discouraged pollution or excessive destruction of natural resources. Collectively, the maps represented sustainability through an interconnected configuration of clean rivers, protected forests, healthy plants and animals, clean community spaces, responsible human behaviour, and continued availability of natural resources. Among the students’ accompanying explanations while presenting the maps that reinforce this interpretation are:

“I put the forest here because we need to keep trees for animals.”(Student 10)

“Our river must be clean because people and animals use it.” (Student 33)

“We keep this place for plants, so people don't destroy everything.”(Student 27)

“This is a clean kampung. We have trees and no rubbish in the river.”(Student 42)

“We need the forest now and also when we grow up.”(Student 18)

These explanations indicate that pupils were not merely reproducing isolated environmental features on their maps. Instead, they increasingly connected ecological protection with the functioning and continuity of their community. The river was represented as a shared resource for humans and animals; forests were associated with habitat protection; plants were conceptualised as resources requiring conservation; and cleanliness was situated alongside broader ecological considerations. Consequently, sustainability became spatially, socially, and ecologically grounded within an environment that pupils could visualise as their own community.

The statement “We need the forest now and also when we grow up” is particularly significant because it introduces a temporal dimension into pupils' environmental reasoning. The statement does not constitute a

sophisticated theoretical understanding of intergenerational sustainability, but it does demonstrate an elementary recognition that environmental resources should remain available beyond immediate present use. The finding should not be interpreted as evidence that pupils had mastered formal sustainability theory; rather, it suggests that they were beginning to understand one of sustainability's central ideas through an age-appropriate and locally meaningful formulation: what is valuable today should not be destroyed in ways that make it unavailable tomorrow.

Previous research on nature-based learning similarly indicates substantial pedagogical potential while cautioning against assuming that merely exposing pupils to nature automatically yields predetermined educational outcomes. Falzon and Conrad's (2024) review of nature-based learning in primary-school environments found evidence of multiple potential educational and developmental benefits, including nature connectedness, but also identified considerable uncertainty concerning which environmental features and pedagogical designs produce particular outcomes. This finding is important for interpreting GOF effectiveness: the apparent development in understanding of sustainability should not be attributed solely to pupils' exposure to nature. Rather, it appears to have emerged through structured pedagogical engagement with nature and community, particularly through activities that require pupils to represent, explain, discuss, and make decisions about desirable environmental conditions.

Mapping Our Heritage is especially important in this regard because it requires pupils to transform sustainability from something they might be told about into something they have to represent and justify. Constructing an ideal sustainable village requires decisions about what should be present, what should be protected, and how human and environmental features should coexist. The activity functioned as a form of contextual translation in which broad sustainability principles associated with SDGs 11 and 15 were translated into rivers, forests, animals, plants, houses, communal spaces, and behaviours that pupils could situate within a recognisable community landscape. In this respect, the educational contribution of GOF lies less in pupils memorising sustainability terminology and more in enabling them to construct understanding of what sustainability might look like in a place that matters to them.

The finding also addresses an important limitation within the wider place-based education literature. Based on Yemini et al.'s (2025) substantial literature review on place-based education, they noted variation in how place is conceptualised and incorporated pedagogically. GOF contributes a contextually grounded example by demonstrating how place can function not merely as a physical setting for instruction but also as a source of knowledge and meaning through which environmental concepts are explored and understood. For Orang Asli pupils, familiar environments, including rivers, forests, flora, fauna, and village surroundings, provide meaningful contexts for English language learning while connecting sustainability concepts to their lived experiences, ecological knowledge, and community realities. By drawing on these local contexts, GOF offers a culturally responsive approach to sustainability education that moves beyond generic global examples and makes environmental learning more relevant to pupils' immediate surroundings.

Theme 3: Emerging Environmental Agency

The third theme represents further qualitative development in which pupils began to move from recognising environmental problems and understanding ecological relationships towards articulating what they and other community members could do in response. Representative propositions included:

"We can tell people not to throw rubbish in the river." (Student 51)

"Our group wants to clean the river together." (Student 30)

"We should protect the forest and not cut too many trees." (Student 49)

"We can teach children and young generation to take care of animals and plants."(Student 5)

"We can plant more trees near our village." (Student 14)

"If we see rubbish, we should pick it up and tell our friends." (Student 23)

The significance of these responses lies in their agentive orientation. Earlier environmental statements predominantly described desirable conditions or prohibited behaviours: rivers should be clean; rubbish should not be discarded; forests should not be made dirty. The later propositions increasingly identified actors and actions: “we can tell”, “our group wants to clean”, “we should protect”, “we can teach”, and “we can plant”. Linguistically and conceptually, pupils began positioning themselves and others within the community as potential contributors to environmental outcomes.

This distinction can be conceptualised as movement from awareness of environmental responsibility towards emerging environmental agency. The term "emerging" is essential, as the data show pupils' proposed actions and expressed intentions, but they do not indicate whether these actions were subsequently implemented or maintained over time. Thus, the finding should not be described as established pro-environmental behavioural change. Instead, it represents an intermediate but educationally important development in which pupils increasingly perceive environmental protection as something that can involve their own decisions and collective actions.

This interpretation is strongly supported by van de Wetering et al. (2022), but their findings also provide an important caution: environmental understanding should not be assumed to automatically translate into sustained environmental action. This distinction is directly relevant to GOF. Statements such as “We can plant more trees near our village” or “Our group wants to clean the river together” provide meaningful evidence of pupils' willingness to conceptualise themselves as environmental actors, but longitudinal evidence would be necessary to determine whether such propositions subsequently became enacted and sustained practices.

GOF's pedagogical design provides an important bridge between understanding and proposed action through Eco Guardians: Speak Up for Our Community! required pupils to work collaboratively around community-oriented environmental initiatives such as a “Save the River” campaign. The activity moved environmental learning beyond receiving information by asking pupils to formulate and communicate possible responses to environmental concerns. This participatory orientation is consistent with the broader environmental education literature synthesised by van de Wetering et al. (2022), which reveals that the majority of the successful environmental education programmes emphasise active student participation, group learning, place-based learning, and field experience to foster environmental outcomes.

A particularly noteworthy proposition is “We can teach children and young generation to take care of animals and plants.” This response extends the environmental agency beyond personal behaviour. The pupil conceptualises environmental responsibility as something that can be communicated and socially transmitted, positioning children not merely as learners but potentially as contributors to environmental learning within their own social networks. Similarly, “If we see rubbish, we should pick it up and tell our friends” combines individual action with peer influence. Although these statements cannot establish actual community impact, they suggest an emerging conception of environmental responsibility as collective rather than exclusively individual.

Overall, the three themes reveal a coherent developmental trajectory in pupils' environmental reasoning across GOF. Theme 1 indicates a broadening from visible environmental cleanliness towards relational ecological awareness; Theme 2 shows that these ecological relationships were increasingly organised into a locally meaningful conception of sustainability; and Theme 3 demonstrates an emerging movement from understanding towards responsibility and proposed environmental action.

CONCLUSION

This study contributes to English language, AI, and sustainability education in indigenous educational contexts by demonstrating the potential of integrating these domains within a single educational intervention rather than addressing them as separate educational priorities. Through the Guardians of Our Future (GOF) programme, culturally and environmentally familiar resources, including local flora and fauna, rivers, forests, and community environments, were incorporated into programme activities to create relevant and accessible contexts for pupils’ learning. More importantly, GOF establishes a knowledge-bridging structure through which English, AI, and nature-based education function as interconnected rather than independent components. Nature-based education draws on pupils’ familiar environments and community experiences as the contextual foundation for learning; English provides the linguistic resources through which pupils can articulate and communicate their existing and

developing knowledge; and AI, when appropriately and ethically mediated, offers additional tools for organising, representing, and documenting that knowledge without displacing local ways of knowing. Through this interconnected structure, sustainability is situated within environments and community realities that pupils can recognise and relate to, enabling the development of new linguistic, technological, and environmental competencies by building on pupils' existing knowledge and lived experiences.

The overall findings provide preliminary empirical support for the educational potential of this integrated approach. Quantitatively, pupils demonstrated substantial pre-to-post increases in perceived English-language competence, with particularly strong improvements in speaking and vocabulary. At the same time, the qualitative findings revealed a progressive development in pupils' environmental understanding: their responses moved beyond general cleanliness-oriented practices towards more differentiated recognition of ecological relationships, locally grounded understandings of sustainability, and proposed environmental actions. AI demonstrated the largest quantitative change and, importantly, was embedded within meaningful environmental and community-oriented activities rather than presented as a stand-alone technological component. Considered together, these findings suggest that the value of GOF lies not only in the improvements observed within individual learning domains, but also in its capacity to connect language learning, technological engagement, and environmental education through pupils' existing environmental and community knowledge.

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should subject programmes similar to Guardians of Our Future (GOF) to more rigorous empirical evaluation to establish the robustness, sustainability, and transferability of their outcomes. A particularly valuable direction would be to employ a quasi-experimental longitudinal design involving an intervention group and a matched comparison group, with measurements conducted at pretest, immediate post-test, and delayed post-test. Such a design would provide stronger evidence for determining whether observed changes can reasonably be associated with programme participation while also establishing whether improvements are retained beyond the immediate intervention period.

Besides that, future studies should complement self-reported English-language outcomes with performance-based measures to obtain more direct evidence of language development. Speaking could be assessed through independently rated oral-performance tasks, vocabulary through receptive and productive vocabulary measures, grammar through contextualised language-use tasks, and writing through performance tasks evaluated using analytic scoring rubrics. Combining these objective measures with self-report instruments would provide a more comprehensive account of both demonstrated language competence and pupils' perceptions of their confidence and ability.

Future investigations should also similarly broaden the assessment of AI literacy and environmental outcomes. Rather than measuring AI primarily through perceived familiarity, confidence, and engagement, subsequent studies could adopt a multidimensional assessment framework encompassing operational knowledge, effective prompting, interpretation and critical evaluation of AI-generated outputs, recognition of AI limitations and misinformation, privacy awareness, ethical judgement, and understanding of when culturally or community-sensitive knowledge should not be shared with AI systems.

Such measures would enable researchers to determine whether increased exposure develops into critical, responsible, and contextually appropriate AI literacy. At the same time, the environmental component would benefit from longitudinal behavioural evidence to establish whether pupils' emerging environmental awareness and proposed actions translate into sustained practices.

Follow-up interviews, teacher observations, family or community reports, pupil-led environmental projects, and direct observation of community-based activities could be conducted several months after the intervention. Triangulating these sources would allow future research to trace progression from environmental awareness and understanding of sustainability to responsibility, agency, and sustained pro-environmental behaviour, thereby providing stronger evidence of the longer-term educational and community contribution of programmes such as GOF.

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