

Original Article

Contextualizing Earth and Space Science Education through Local Environmental Issues

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Abstract

Contextualizing Earth and Space Science instruction provides greater opportunities for learners to create meaningful learning in an authentic setting. This study examined the impacts of sand dredging in Ilocos Sur and explored how these issues can be integrated into the Earth and Space Science curriculum. A qualitative case study design was employed, involving twelve purposively selected participants, including fisherfolk, coastal residents, barangay officials, and students. The collected data were analyzed thematically, and curriculum mapping was conducted to integrate the themes identified with the competencies in Grade 11 Earth and Space Science. It was found that there were six key themes: coastal erosion and shoreline retreat; sediment transport and river mouth dynamics; marine biodiversity loss and ecosystem destruction; socioeconomic impacts on coastal communities; climate resilience and disaster risk; and policy and governance gaps. Many of the themes were found to be closely related to core curriculum themes, standards, and competencies. It also revealed that these localized environmental issues can be turned into contextualized learning activities that nurture critical thinking, environmental literacy, and civic involvement among learners. Among the identified curriculum integration models, the theme-based model appeared to offer the strongest alignment with the environmental themes and competencies in the Earth and Space Science curriculum, providing meaningful, relevant, and community-oriented learning experiences.

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1. Introduction

Contextualizing features of the curriculum, such as integrating local environmental issues, plays a critical role in developing scientific literacy and responsible stewardship, especially among Filipino learners. The recent curriculum reform for senior high school, with its pilot implementation, demonstrates that integrating environmental education into subjects like Earth and Space Science acknowledges the need for more relevant, context-based learning. Beyond theoretical and conceptual knowledge, Earth and Space Science offers students opportunities to explore and develop solutions to real-world environmental issues that directly affect them and their communities. However, the integration of localized environmental concerns into science instruction remains limited, often resulting in a disconnect between classroom practice and students' lived experiences.

Environmental degradation is one of the most urgent issues of the past few decades, affecting poor and marginalized communities and largely caused by the unsustainable use of natural resources through industrialization, deforestation, unsustainable population growth, and other human activities. These activities have a significant impact on biodiversity loss, ecological imbalance, and greenhouse gas emissions, which negatively affect the environment and human health and threaten environmental sustainability and well-being (Abbas et al., 2024). Within the context of coastal communities and local islands, sand dredging, the method of obtaining sand from riverbeds, coastal regions, and marine environments, has become a major factor in environmental degradation. This activity disrupts aquatic ecosystems, river structures, and coastal morphology, leading to biodiversity loss. Sand and gravel extraction from rivers, while essential for construction and infrastructure development, can cause significant environmental impacts, including habitat disturbance, alterations in sediment transport, degradation of aquatic ecosystems, and increased riverbank instability and erosion (KoeHNken et al., 2020). Worldwide, sand extraction leads to erosion of coastlines and riverbanks, destruction of habitats, water contamination, and the disturbance of aquatic ecosystems (Jouffray, 2025). It also exacerbates climate vulnerabilities by destabilizing natural flood defenses, destroying coastal and island shores and riverbeds, and releasing pollutants into water systems (Torres et al., 2025).

The environmental effects of sand extraction have been reported in various parts of the world, but these effects are not just global issues; they are now a local reality. In numerous countries where sand is dredged from rivers and coasts, environmental degradation, such as shoreline erosion, habitat loss, biodiversity loss, disruption of sediment transport, and increased risk from climate-related hazards, has been reported. In the province of Ilocos Sur, there have been cases of coastal erosion, a reduction in

fishing catch, and changes in the coastal environment reported in the communities along the Abra River's mouth. The local situation is indicative of the global pattern, which shows how multiple unsustainable patterns of resource extraction can result in community-specific environmental problems. An examination of the Abra River case provides insight into the local experiences of global environmental issues and how these experiences can serve as relevant contexts for science learning. In the Philippines, sand dredging has sparked national concern due to its environmental and social consequences. The province of Ilocos Sur has become one of the victims of these degradation activities. Sand dredging in some areas of the province has sparked widespread concern among residents, environmental groups, and local officials due to its adverse ecological and social impacts. The operations were initially framed as flood mitigation efforts along the Abra River and its inlet shared by Santa, Caoayan, and Vigan City (Ilocos Center for Research, Empowerment, and Development [ICRED], 2025). However, local communities have reported coastal erosion, displacement of fisherfolk, nighttime dredging, and a dramatic decline in fish catch, particularly of goby fry (ipon), which has led to food insecurity and reduced income (Sinaking, 2025).

Based on the results of Buyanetah and Villocido (2025), Earth Science education in the Philippines often lacks contextualized content that reflects local ecological challenges, such as sand dredging and its impacts on communities. This gap limits students' ability to connect scientific concepts with real-world environmental concerns in their own regions. Integrating local environmental cases, such as the impacts of sand dredging in Ilocos Sur, into the curriculum can foster deeper understanding, critical thinking, and civic engagement among learners. Such integration aligns with the Department of Education's Most Essential Learning Competencies (MELCs), which emphasize contextualization and the relevance of learning to students' lived experiences (Department of Education, 2015). By embedding region-specific environmental issues into Earth Science instruction, educators can promote environmental literacy and empower students to become proactive stewards of their communities.

Finally, the environmental impacts of sand dredging provide authentic examples that enable students to make science real in their community. Relying on textbook cases to study environmental processes, learners can study phenomena they observe in the real world or experience firsthand. This is consistent with constructivist approaches to learning, in which knowledge is actively built through engagement with the environment and prior experiences. Learners have the opportunity to engage with environmental issues affecting the local community, including coastal erosion, biodiversity loss, and the environmental impacts of sand dredging, fostering deeper conceptual understanding and helping students become more environmentally aware and responsible citizens. Thus, if Earth and Space Science is to be made meaningful and relevant to students, it should be connected to their immediate environment and the issues it faces. This approach is strongly grounded in constructivism, which posits that learners construct knowledge from their prior experiences and interactions with their environment. According to the constructivist perspective, learning is meaningful

when students relate new knowledge to their existing knowledge structures, thereby enhancing their conceptual learning. Loyens and Gijbels (2008) emphasized that constructivist learning environments lead to active knowledge building, in which the learners relate new information to their existing knowledge and experiences. Learning is not a passive process but an active one, in which learners investigate, question, interpret, and reflect on real-world phenomena. These experiences allow students to build more lasting and significant knowledge of scientific concepts.

This study aimed to examine the observed environmental changes associated with sand dredging in Ilocos Sur, drawing on observational findings, interview insights, and a systematic review of relevant online resources and data. The investigation sought to identify Earth and Space Science concepts closely related to documented local environmental issues and to explore how these findings can inform the design and planning of learning activities in the strengthened Senior High School (SHS) curriculum. Furthermore, the study aimed to determine an appropriate curriculum integration model to effectively embed local environmental issues into the Earth and Space Science subject within the newly strengthened SHS program, thereby contextualizing the curriculum's features.

2. Methodology

This study employed a qualitative case study design to explore the environmental impacts of sand dredging and to integrate the findings into the Earth and Space Science Curriculum for Senior High School through a qualitative curriculum mapping approach. A qualitative case study design is an approach used to gain an in-depth understanding of a phenomenon, individual, or group within a real-life context. It enables researchers to explore more complex social phenomena using multiple sources, providing rich, detailed, and contextualized data to understand respondents' experiences and perspectives (Priya, 2021). The research was conducted in selected coastal barangays of Santa and Caoayan, Ilocos Sur, which are significantly affected by sand dredging activities along the Abra River and its mouth. The study population consisted of 12 purposively selected respondents. The participants consisted of fisherfolk who were actively fishing in the mouth of the Abra and its nearby coastal waters, long-term residents of the coastal communities, barangay officials who were knowledgeable about the local environmental and governance issues and senior high school students who lived in the affected areas who showed their local concern on environmental issues. To make the data credible and rich, participants had to have lived, worked, studied, or served in the community during the dredging activity and the associated environmental effects being observed. These sites were chosen to ensure that the findings reflected authentic and localized conditions relevant to both environmental analysis and curriculum contextualization. For the next phase, curriculum mapping was used to analyze and integrate the case study results into the Earth and Space Science subject in the newly strengthened senior high school program.

There were two phases in the conduct of this study: the first phase included a case study and thematic analysis, and the second phase was curriculum mapping based on the themes generated from the case study to contextualize the curriculum. For the initial phase, multiple data collection tools were used to triangulate findings. Field observations were conducted to document visible environmental changes that happened in the area along the river and sea coastlines of Santa and Coayan, Ilocos Sur. Semi-structured interviews were conducted with key informants, including fisherfolk, residents living near the coasts all their lives, barangay officials, and students, to capture firsthand accounts of environmental impacts. An adapted questionnaire, originally developed by Tarr (2023), was used and modified to align with the local context and research objectives. In addition, a systematic review of secondary data was conducted using verified online sources, including government reports, academic studies, and credible news articles documenting sand dredging activities in Ilocos Sur. In mapping the science curriculum, specifically the Earth and Space Science, the researcher utilized the curriculum guide provided by the Department of Education for the pilot implementation of the Strengthened SHS Program, to integrate the themes into the concepts, learning competencies, and performance standards present in the curriculum guide to ensure curriculum alignment and correct integration with appropriate features of contextualization.

Qualitative data from observations, interviews, and secondary sources, such as online sources, were analyzed using thematic analysis, allowing recurring patterns and themes to emerge across data sources. Guided by Priya (2021) the framework allows for a thorough investigation of contextual factors using a variety of data sources and is suitable for studying a phenomenon in its natural environment. A systematic thematic analysis procedure was used to analyze the qualitative data obtained. First, all the field notes, interview transcripts, and documentary sources were reviewed several times to facilitate data familiarization. Second, initial codes were assigned to meaningful statements, observations and recurring ideas related to the impacts of sand dredging. Thirdly, codes were clustered into overarching categories, which were potential themes. Fourth, the preliminary themes were discussed, edited together, and compared across the data sources for consistency and to eliminate overlaps. Fifth, the meaning and evidence for each theme were clearly identified and labeled. Last of all, the themes that emerged were interpreted and confirmed through data triangulation, which involved observational records, participant stories, and secondary documents. The themes were then finalized and used as the basis for the curriculum mapping process and for identifying contextualized learning opportunities within the Earth and Space Science curriculum. The results from the case study phase served as the empirical basis for the second stage of the research, which focused on curriculum mapping. Curriculum mapping is a systematic process of aligning the features of the curriculum, such as content, outcomes, strategies, assessments, and standards, to identify gaps, overlaps, and opportunities for improving the curriculum (Rawle et al., 2017).

This study documented environmental and socioeconomic changes observed in communities affected by sand dredging activities through field observations, stakeholder interviews, and secondary sources. However, the qualitative case study design does not allow for definitive causal attribution between dredging operations and the identified themes. Other factors, such as typhoons, natural river migration, seasonal sediment transport, coastal processes, climate-related events, and other human activities, may also contribute to the observed environmental conditions. Therefore, the findings should be interpreted as perceived and observed changes associated with dredging activities rather than conclusive evidence that dredging alone caused these changes. Future studies employing longitudinal environmental monitoring, geospatial analyses, hydrodynamic modeling, and water or sediment quality assessments are recommended to determine causal relationships better and quantify the relative contribution of dredging to environmental change.

In this study, curriculum mapping was done by systematically aligning the documented local impacts of sand dredging in Santa and Caoayan, Ilocos Sur, with the Grade 11 Earth and Space Science learning competencies of the Strengthened Senior High School curriculum. The process began with identifying key environmental, socioeconomic, and governance issues emerging from field observations, interviews, and secondary data, which were then used as contextual anchors. These issues were mapped to relevant Earth Science concepts through curriculum unpacking to ensure alignment with existing content standards and learning competencies. The mapping results informed the design and planning of learning activities by translating mapped competencies into locally grounded tasks that promote higher-order thinking, problem-solving, and environmental awareness.

Following the curriculum mapping process, the three curriculum integration models found by Loepp (1999) were analyzed using a document analysis technique, namely the interdisciplinary model, problem-based model and theme-based model. The researchers compared using predetermined criteria based on a literature review, such as alignment of the curriculum, local relevance, higher-order thinking, coherence in competency integration, and classroom feasibility. The analysis was not meant to be an empirical test of the models' effectiveness, but rather an informed assessment of possible integration approaches. No weighting scheme, external validation or expert rating procedure was used, so the findings should be treated as an analytical recommendation based on the curriculum mapping results.

3. Results

3.1 Observed Environmental Changes Associated with Sand Dredging Activities

Theme 1: Coastal Erosion and Shoreline Retreat

The results showed that coastal erosion and shoreline retreat have become more severe in Barangay Oribi and Puro, mainly due to dredging activities in the Abra River. Field observations show a significant loss of coastal vegetation, especially mangroves, with degradation affecting properties along the coastline, indicating significant environmental degradation. Interviews with residents confirm these observations and describe the loss of land features such as Snake Island and the reduction in spaces for community activities. These claims are also corroborated by secondary sources that report increased erosion and land subsidence due to large-scale dredging and suspected sand mining for black sand. These activities have long-term impacts on coastal stability, and these impacts need to be addressed through sustainable dredging practices to minimize additional ecological and socio-economic effects.

Field visits revealed significant evidence of shoreline retreat and erosion, particularly along the shoreline of barangays Oribi and Puro. The shore and riverbanks around the island showed a noticeable narrowing. Coastal vegetation, such as mangroves, has diminished considerably, widening the area of the Abra River. Several beachfront structures, such as cottages and seawalls, exhibit signs of undermining and partial collapse due to persistent wave scouring. Participants mentioned:

“Marunot kami ditoyen, ado nga parte tuy islan ti nateppang sipod pay idi nagdredging da ditoy.” (We’re already being eroded here; many parts of the island have disappeared since they started dredging near the island.) (P1)

“Adda idi makunkuna nga Snake Island ditoy asideg barangay mi (Oribi) ngem naawan nga ininot jay isla, attan pulos awanen.” (We have an island here called Snake Island near our barangay, but it gradually disappeared, and now it’s completely gone.) (P3)

“Idi ket kaya mi pay agayayam nu Intrams ditoy igid isla kasjay kalawa idi ditoy.” (Back then, we could even play here along the side of the island during intramurals, that’s how wide it used to be.) (P10)

According to the Feature article by De Vera and Lam-ing (2025) of Northern Dispatch, there are reports of faster-eroding shorelines in Barangay Puro, Caoayan, due to dredging operations. Locals report land subsidence and destruction of homes. Marine geologist Dr. Fernando Siringan warned that large-scale offshore dredging could damage coastlines and recommended smaller vessels for river dredging instead, as mentioned in the said article.

Furthermore, a research study published by Inquirer on October 16, 2025, reported an environmental issue in the Abra River, Ilocos Sur, with Black sand extraction suspected behind the dredging operations. One of the observed impacts of the said operation is rapid beach erosion, as reported by fisherfolk and coastal residents since dredging began in 2024. Residents noticed accelerated shoreline retreat, proof of environmental risks in the area.



Figure 1. Satellite image of Barangay Puro, Oribi and Dammay in the Municipalities of Sant and Caoayan, Ilocos Sur in 2018.



Figure 2. Satellite image of Barangay Puro, Oribi and Dammay in the Municipalities of Sant and Caoayan, Ilocos Sur in 2025.

Further analysis of the satellite images suggests measurable changes in the landscape between 2018 and 2025. The length of the island separating Abra River and Lagben River decreased by 212.59 meters or about 9.5% from 2,231.96 meters in 2018 to 2,019.37 meters in 2025. The largest decreases were observed along the western and eastern parts of the island, where shoreline recession was evident. These measurements provide quantitative support for observations of coastal erosion and corroborate residents' perceptions of the gradual loss of landforms and community areas in the coastal zone.

Theme 2: Sediment Transport and River Mouth Dynamics

Recent observations and community accounts indicate that dredging along the Abra River has significantly altered sediment transport and river-mouth dynamics, reshaping coastal morphology. Field data show deltaic expansion and high turbidity levels, suggesting intensified sediment suspension and redistribution. Interviews reveal local concerns about persistent dredging, with residents noting changes in river shape and stronger currents during heavy rains, which may exacerbate erosion risks. Secondary sources confirm that large-scale dredging has displaced millions of cubic meters of material, disrupting natural sediment replenishment and weakening coastal defenses. These findings underscore the complex interplay between human interventions and fluvial processes, raising urgent questions about long-term ecological stability and community resilience. Recent field observations revealed alterations in the Abra River's cross-section and flow patterns, thereby influencing the coastal morphology. The river mouth shows evidence of deltaic expansion, with new depositional structures reaching seaward. The turbidity levels in the river water are quite noticeable, suggesting strong sediment suspension and transport in the area. Participants verbalized:

"Adda idi ti gundaway nga nagayab da ijjay barko ket inpakita da nga darat lang nga aggpayso ti alalaen da ijjay karayan ken jay kabaybayan." (There was a time when they invited us to go onto the ship to show us that they were really only extracting sand from the river and the coastline.) (P7)

"Nu ti rabii nagpigsa danarudor ken uni dagiti barko nag arigna dikampay makaturug, senyales na ajay nga madama sand dredging da manen." (At night, the sound of their ships is so loud that we can hardly sleep—it's a sign that they're extracting sand again.) (P2)

"Nu napigsa ti tudo ket ngumato ti danom sabsabali nukwa ti pigsa ti dalluyon agalalo ta kasla sabali payen ti porma daytoy karayan min." (When the rain is heavy and the water level rises, the waves become stronger, especially since the shape of our river seems different now.) (P4)

Based on the report entitled "Conflicting tides: Abra River dredging project sparks concerns, divides residents," dredging at the Abra River delta (Barangay Puro, Caoayan) highlights its impact on river mouth morphology and sediment redistribution. Notes that over 8 million cubic meters of dredged material were moved for reclamation projects, altering sediment flow and stability of riverbanks. Moreover, findings from the focus group discussions and field assessments in five affected barangays (Puro, Tamurong, Dammay, and nearby coastal areas) conducted by Ilocos Center for Research, Empowerment and Development (ICRED) revealed that Offshore dredging disrupts sediment transport, reducing natural replenishment at the river mouth and weakening coastal defenses.

Theme 3: Marine Biodiversity Loss and Ecosystem Destruction

Field observations and community testimonies reveal a marked decline in marine biodiversity and ecosystem health along the Abra River mouth and adjacent coastal areas. Fisherfolk report reduced catches of “ipon” and other species, while some fish exhibit unusual gasoline-like flavors, suggesting contamination from dredging activities. The loss of mangrove coverage in barangays Puro, Dammay, and Oribi further indicates habitat destruction, weakening natural coastal defenses and disrupting ecological balance. Secondary reports corroborate these findings, linking large-scale dredging and offshore extraction to severe drops in fish populations and the displacement of local livelihoods. These patterns highlight the cascading ecological impacts of dredging, threatening food security and the sustainability of coastal ecosystems. During the field visit in August 2025, “ipon” fish appeared, and local fisherfolk were able to catch them, but there was a noticeable decline in the catch of local fishermen that season. There is also a noticeable decrease in the coverage of mangrove trees around the coastlines of Brgy. Puro, Dammay and Oribi in the towns of Caoayan and Santa, Ilocos Sur. Participants highlighted:

“Bimmasit ti maalala min nga ipon ken dadduma pay nga ikan agsipud immay da nagdredging dito.” (Our catch of ipon and other fish decreased after they came to dredge sand.) (P6)

“Adda pay tay maala mi nga ikan nu iluto ken ramanana mi agat gas.” (There were even times when the fish we caught, once cooked and tasted, had a gasoline-like flavor.) (P3)

“Gapo agitoy masagsagrap ita tuy isla mi kas koma ti napigsa nga dalluyon ken pannakateppang ti daga, adda dagiti tangrib nga naawanen.” (Because of what’s happening to our island, such as the strong waves and erosion, the mangrove coverage has decreased.) (P4)

The published data from the reports of PAMALAKAYA, a local group in Ilocos Sur, in an article by Inquirer.Net, showed severe declines in fish catch due to dredging vessels disturbing marine life at the Abra River mouth, signaling an ecosystem imbalance. Additionally, dredging in the Abra River and offshore areas has devastated marine ecosystems and displaced livelihoods in Santa, Caoayan, and Vigan. ICRED reports classify the project as a “thinly veiled extraction” that harms biodiversity. The reduction in fish catch and the degradation of coastal habitats observed in this study are consistent with documented effects of dredging on aquatic ecosystems. Fisherfolk have reported a decline in the abundance of ipon and other fish species, and field observations have indicated a decrease in mangrove cover along the affected coastlines. Also, Koehnken et al. (2020) reported that sand extraction can adversely affect fish, fish habitat, food webs, and biological communities by disrupting habitats and altering sediment dynamics. Also, research on dredging operations has revealed that sediment disturbance increases water turbidity and resuspends sediment, which

can adversely affect water quality and aquatic life. Environmental assessments have also indicated that dredging operations can mobilize contaminants attached to sediment and alter ecological conditions in impacted water bodies. Participant reports of a gasoline-like smell or taste in fish cannot be confirmed or refuted as a scientific finding within the scope of this study, as there have been no laboratory analyses. However, they may be related to perceived changes in the environment associated with sediment disturbance and should be further investigated. The results, taken together, highlight the potential for long-term effects of dredging on biodiversity, fisheries production, and coastal ecosystem integrity.

Theme 4: Socioeconomic Impacts on Coastal Communities

The socioeconomic consequences of dredging along the Abra River are evident in declining fish catches, forcing many coastal residents to abandon traditional fishing and aquaculture for alternative livelihoods such as agriculture and tourism-related work. Observations confirm reduced fishing activity and the disappearance of cultural landmarks like Snake Island, which had potential for tourism development. Interviews highlight growing hardship as fisherfolk travel farther offshore, incurring higher fuel costs, while secondary reports reveal income losses of 80–90%, food insecurity, and the displacement of over 6,800 residents. These trends underscore the vulnerability of coastal communities to environmental disruptions, threatening both economic stability and cultural heritage. Observations made during the third quarter of the year, specifically on the shores of Puro, Caoayan, and riverbanks in Oribi, Santa, showed reduced catch volumes and only a few fishermen going fishing during that season. These forces many residents to seek alternative livelihoods, such as switching to agricultural activities and tourism-related jobs. Additionally, traditional practices such as small-scale aquaculture and coastal farming are becoming less viable, further threatening food security and cultural heritage. Participants expressed:

“Rumigrigat ti mapan agkalap tattan ta uray da lang umadayo bassiten ditoy isla makakalap da lang.” (Catching fish is becoming more and more difficult, they even have to go farther out just to catch anything.) (P2)

“Dayjay Snake Island mi idi haan pay nga nateppang adda koma proyekto ti local a gobyerno nga pagbalinen da nga tourism site, ado pay kubo kada cottage na idi dijayen ngem tattan awanen.”(Our Snake Island before it disappeared, there was already a plan by the local government to turn it into a tourism site. There were huts and cottages there, but now it’s gone.) (P8)

“Inawan daytoy dredging ti ikan nga makalkalapan mi.” (This dredging destroyed the fish we used to catch.) (P6)

According to an article by Bulatlat contributors (2025), early in 200, 200 fisherfolk and residents protested dredging in the Abra River, citing the displacement of livelihoods and a lack of consultation. ICRED reports over 6,800 residents affected,

with income loss and food insecurity. Furthermore, ICRED estimates over 500 residents in immediate impact areas rely on fishing. Noise and vibrations from dredging vessels drive fish away, causing a severe decline in income.

Theme 5: Climate Resilience and Disaster Risk

Despite some adaptive measures such as seawalls and evacuation centers in barangays like Oribi, overall climate resilience remains weak due to inadequate household-level flood protection and limited resources. Observations reveal heightened vulnerability to typhoons and storm surges, with infrastructure damage and prolonged recovery periods becoming more frequent. Interviews confirm residents' struggles with worsening floods and rising water levels, while local officials allocate most funds to disaster mitigation projects, signaling resource strain. Secondary sources argue that dredging, initially justified as a flood control measure, has instead increased disaster risk by accelerating shoreline erosion and destabilizing riverbanks. These findings highlight critical gaps in preparedness and infrastructure that undermine long-term resilience against climate hazards. A recent observational assessment revealed that barangays like Oribi in Santa Ilocos Sur have mitigation efforts against the potential impacts of soil erosion and flooding by building stronger structures along shorelines and riverbanks, such as a seawall, and constructing two-story evacuation centers. Many households lack adequate flood protection measures, with only a small percentage equipped with elevated housing or reinforced structures. Coastlines are very prone to the impacts of large waves, and infrastructure damage is also noticeable in areas around Puro, Caoayan, which strains local resources, and recovery periods have lengthened over the past years. Although adaptive measures are present, vulnerability remains high due to gaps in preparedness, infrastructure, and resource availability. Participants mentioned:

“Nu adda ti bagyo nalaka kam lang malaylayusen, ikomparam idi napalpalabas nga panawen.” (When there’s a typhoon, it’s now easier for us to get flooded compared to before.) (P4)

“Dakkel ti alon nga isu met paggapwan ti ingangato ti danom, adda idi napalabas nga tawen dimmanon ti pagat-sibet nga layos.” (The big waves also cause the water level to rise. Last year, the floodwater reached up to waist level.) (P2)

“Amin nga maalala mi nga pondo ipapaay mi amin ti proyekto ditoy barangay mi tapno haan kami unay maapektaran dagitoy a didigra.” (All the funds we receive are allocated to barangay projects so that we won’t be as affected by natural disasters.) (P9)

In an online article by De Vera (2025), dredging was justified as a flood mitigation measure, but ICRED and local groups argue that it worsens vulnerability by eroding coastlines and destabilizing riverbanks. Offshore dredging disrupts natural

sediment flow, increasing the risk of disasters during typhoons and storm surges. Furthermore, dredging operations intended for flood control have led to shoreline retreat and structural instability, raising concerns about long-term resilience against climate hazards.

Theme 6: Policy and Governance Gaps

Field assessments and interviews reveal critical governance shortcomings in managing coastal and riverine impacts of dredging. Community consultations are minimal, leaving residents with limited opportunities to participate and be aware, while protests highlight growing dissatisfaction. Although nearby municipalities like Narvacan have enacted anti-dredging policies, affected areas such as Santa and Caoayan lack clear regulations, creating enforcement gaps. Secondary sources confirm that dredging operations exceeded their flood-control mandate, with millions of cubic meters of sand diverted to reclamation projects, facilitated by weak oversight by permitting agencies such as the Department of Environment and Natural Resources (DENR) and the Department of Public Works and Highways (DPWH). These findings underscore systemic governance failures, inadequate transparency, and the absence of localized policy frameworks, which collectively exacerbate environmental and socioeconomic vulnerabilities. Field assessments and stakeholder interviews reveal significant gaps in policy implementation and governance related to coastal management. Community consultations are often minimal, resulting in low awareness and participation in decision-making processes. Residents and fishermen have held fluvial protests condemning the impacts of sand dredging. Nearby municipalities like Narvacan have drafted resolutions and executive orders against black sand mining and sand dredging; however, Santa and Caoayan do not have any policies regarding sand dredging. Participants expressed:

“Nu adda maang-angay nga meeting ni Kapitan mi ti mapmapan makitatariknong, ken adda met statement ni Mayor ken ti probinsya mainaig ti sand dredging.” (When there are meetings, the barangay captain attends to discuss the matter. The mayor also issues statements, as well as the provincial government, regarding the sand dredging.) (P1)

“Adda maang-angay nga protesta kada rally nga dumardar-ayan dagiti dadduma nga taga-ditoy kas panangipakita mi ti nagbalin nga epekto na ti dredging.” (There are protests and rallies organized by the locals to show the impact of the dredging.) (P8)

According to the article by Sinaking (2025), there is a lack of proper consultation and consent from affected communities. ICRED reports that dredging exceeded its flood-control mandate and became a “thinly veiled extraction project,” with sand shipped to Manila Bay reclamation sites. Additionally, De Vera (2025) stressed that DENR and DPWH issued permits, but oversight failed to prevent large-scale

extraction. The Mines and Geosciences Bureau confirmed the transfer of 8 million cubic meters of dredged material for reclamation projects, despite a flood-control justification.

3.2 Integrating Earth and Space Science through Local Environmental Issues

The matrix indicates that the identified impacts of sand dredging, through the themes that emerged can be meaningfully integrated into the Grade 11 Earth and Space Science subject of the Strengthened Senior High School curriculum as it is aligned with existing content standards and competencies. Specifically, topics on weathering, erosion, and sedimentation allow discussion of how dredging accelerates shoreline retreat and alters river dynamics, while surface water and groundwater systems connect to its effects on marine ecosystems and water quality. Additionally, lessons on mineral resources provide opportunities to address dredging as a form of resource exploitation and its socioeconomic implications for coastal communities. These links enable teachers to contextualize abstract Earth Science concepts with real-world issues, fostering environmental awareness and critical thinking through case-based learning.

Table 1. Learning competencies matrix for Earth and Space Science.

Environmental Impact of Sand Dredging	Aligned Curriculum Standards		
	Content	Content Standard	Learning Competencies
Theme 1: Coastal Erosion and Shoreline Retreat	Weathering, erosion, and sedimentation	The learners learn that weathering, erosion, and sedimentation are processes that continually reshape Earth's surface.	Explain weathering, erosion, and sedimentation in shaping the Earth's surface. Describe coastal and riverine processes, highlighting landscapes through erosion, deposition, and transportation of materials.
Theme 2: Sediment Transport and River Mouth Dynamics	Weathering, erosion, and sedimentation	The learners learn that weathering, erosion, and sedimentation are processes that continually reshape Earth's surface.	Describe the coastal and riverine processes, highlighting erosion, deposition, and transportation of materials. Develop a summary of events that influenced the current shape of the Philippine Archipelago
Theme 3: Marine Biodiversity Loss and Ecosystem Destruction	Surface Water and Groundwater Systems	The learners learn that water in different forms plays a vital role in forming landscapes, supporting ecosystems, and sustaining human needs.	Explain the importance of surface water and groundwater systems in supporting ecosystems Propose sustainable ways of conserving and protecting

		Human activities have a profound impact on water quality and availability.	water resources caused by human activities
Theme 4: Socioeconomic Impacts on Coastal Communities	Mineral resources	The learners learn that minerals are essential for industrial development, economic growth, and technological advancement, but should be managed sustainably.	Identify strategies to prevent and mitigate the environmental impacts associated with the exploitation, over-extraction, and misuse of mineral resources.
Theme 5: Climate Resilience and Disaster Risk	Weathering, erosion, and sedimentation	The learners learn that weathering, erosion, and sedimentation are processes that continually reshape Earth's surface.	Describe coastal and riverine processes, highlighting landscapes through erosion, deposition, and transportation of materials.
Theme 6: Policy and Governance Gaps	Surface Water and Groundwater Systems	The learners learn that human activities have a profound impact on water quality and availability.	Describe and evaluate how Philippine water and other resources are being monitored through various government agencies; and Propose sustainable ways of conserving and protecting water resources caused by human activities.

3.3 Contextualization of Competencies through Environmental Themes

Table 2 translates the environmental impacts of sand dredging into concrete learning opportunities by linking the learning competencies in the Earth and Space Science curriculum with learner-centered classroom activities. The proposed learning activities, such as the shoreline simulation and analysis, pathway mapping, water conservation proposal, hazard mapping, and local policy critique, are designed to actively engage students in higher-order thinking and applied problem-solving while ensuring alignment with the competencies in the curriculum. This conversion demonstrates how sand dredging impacts can function not only as instructional content but also as a full context for developing critical thinking, environmental awareness, and civic responsibility among learners.

Table 2. Conversion of themes into learning opportunities.

Environmental Impact of Sand Dredging	Learning Competencies	Possible Learning Activity
Theme 1: Coastal Erosion and Shoreline Retreat	Explain weathering, erosion, and sedimentation in shaping the Earth's surface.	Dynamic GEO-interplay: Mini Coastal Erosion Simulation

	Describe coastal and riverine processes, highlighting landscapes through erosion, deposition, and transportation of materials.	Investigating Satellite Images: Before-and-After Shoreline Analysis
Theme 2: Sediment Transport and River Mouth Dynamics	Describe the coastal and riverine processes, highlighting erosion, deposition, and transportation of materials. Develop a summary of events that influenced the current shape of the Philippine Archipelago	Riverine Chronicles: River to Sea Sediment Pathway Mapping Domination in Coastal Formation: Cause and Effect Timeline
Theme 3: Marine Biodiversity Loss and Ecosystem Destruction	Explain the importance of surface water and groundwater systems in supporting ecosystems Propose sustainable ways of conserving and protecting water resources caused by human activities	Marine Life, Marine Strife: Ecosystem Impact Web (Concept Map) Local Water Conservation Proposal
Theme 4: Socioeconomic Impacts on Coastal Communities	Identify strategies to prevent and mitigate the environmental impacts associated with the exploitation, over-extraction, and misuse of mineral resources.	Community Stakeholder Role-Play Case to Social Costs: Cost-Benefit Analysis Chart
Theme 5: Climate Resilience and Disaster Risk	Describe coastal and riverine processes, highlighting landscapes through erosion, deposition, and transportation of materials.	Cry of the River: Hazard Mapping Activity For Protection and Mitigation: Resilience Design Challenge
Theme 6: Policy and Governance Gaps	Describe and evaluate how Philippine water and other resources are being monitored through various government agencies; and Propose sustainable ways of conserving and protecting water resources caused by human activities.	Who's Who! Agency Mapping Task Local Policy Critique and Recommendation

3.4 Comparative Analysis of Curriculum Integration Models for Contextualized Earth and Space Science Instruction

Table 3 compares three curriculum integration models based on Loepp's (1991) article: Interdisciplinary, Problem-Based, and Theme-Based. In determining their suitability for embedding sand dredging impacts in SHS Earth and Space Science, the criteria included curriculum alignment, relevance to real-world contexts, depth of conceptual understanding, support for inquiry and higher-order thinking, and feasibility of classroom implementation. Based on the curriculum mapping analysis, the theme-based model appeared to provide the strongest alignment between the identified environmental themes and Earth and Space Science competencies. However, this interpretation should be viewed as an analytical recommendation rather than a definitive measure of effectiveness. The table highlights that a theme-based

model effectively balances curriculum fidelity with contextual relevance, making it especially appropriate for teaching complex, multifaceted issues such as sand dredging and its impacts.

Table 3. Comparison of curriculum integration models on embedding sand dredging impacts in SHS Earth & Space Science.

Curriculum Integration Model	Core Features	Evidence based on the Themes	Alignment with the Curriculum	Suitability
Interdisciplinary Model	Groups traditional subjects into coordinated blocks Maintains disciplinary boundaries while promoting collaboration Teachers plan jointly around shared issues or contexts	Theme 1 (Coastal Erosion) and Theme 2 (Sediment Transport) naturally integrate Earth Science concepts with Geography, Social Studies, and Disaster Risk Studies Theme 4 (Socioeconomic Impacts) links Earth & Space Science with Economics and Social Science through livelihood loss and community displacement data	Strong alignment with DepEd SHS curriculum since Earth & Space Science competencies are addressed explicitly Disciplinary standards remain intact while contextualized through real-world sand dredging impacts	Moderate to High
Problem-Based Model	Real-world problems serve as the core of instruction Disciplines contribute concepts and skills to solve an authentic issue Emphasizes inquiry, critical thinking, and evidence-based solutions	Themes 1, 2, and 5 frame sand dredging as a concrete environmental problem involving erosion, flooding, and disaster risk Theme 3 (Marine Biodiversity Loss) and Theme 6 (Policy Gaps) provide authentic datasets for investigating human-environment interactions and governance failures	Highly consistent with learner-centered, inquiry-based competencies (e.g., proposing sustainable solutions, evaluating human impacts) Supports performance-based assessment and higher-order thinking emphasized in SHS Earth & Space Science	High
Theme-Based Model	Curriculum organized around a unifying theme	All six themes (Coastal Erosion, Sediment Transport, Biodiversity Loss, Socioeconomic Impacts, Climate Risk,	Very strong alignment with DepEd curriculum structure	Very High

	Discipline-specific objectives are selected to support the theme Easier alignment with standards and learning competencies	Policy Gaps) can be unified under the theme “Human Impacts on Earth’s Surface Systems” Learning activities (hazard mapping, policy critique, ecosystem concept mapping) directly emerge from the themes	Each theme maps cleanly to specific quarters and content standards (Earth’s Processes, Surface Systems, Resources, and Governance)	
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4. Discussion

This study identified environmental changes associated with dredging activities in coastal areas of Ilocos Sur, particularly in Santa and Caoayan. It determined how these identified impacts can be integrated into the Senior High School (SHS) Earth and Space Curriculum as presented in the new Strengthened SHS Program.

The results of the study showed an underlying multidimensional environmental impact of sand dredging perceived by the participants. These impacts align strongly with the existing Grade 11 Earth and Space Science learning competencies, and the most suitable curriculum integration model was also identified based on criteria including curriculum alignment, relevance to real-world contexts, depth of conceptual understanding, support for inquiry and higher-order thinking, and feasibility of classroom implementation.

Based on the themes that emerged from the observational findings, interview insights, and data from online and secondary sources, there are six major environmental impacts of sand dredging in Ilocos Sur: coastal erosion and shoreline retreat, sediment transport and river mouth dynamics, marine biodiversity loss and ecosystem destruction, socioeconomic impacts on coastal communities, climate resilience and disaster risk, and policy and governance gaps. These themes are consistent with earlier studies showing that sand extraction modifies riverine and coastal natural processes, resulting in significant ecological repercussions, including coastal erosion and shoreline retreat, among the most frequently reported impacts (Koenken et al., 2020). Global evaluations also verify that habitat degradation and turbidity caused by dredging reduce fish stocks and harm mangrove ecosystems, thereby undermining livelihoods that depend on fishing, as supported by Torres et al. (2025). Furthermore, the impact on disaster vulnerability aligns with recent interdisciplinary evaluations by Gacu et al. (2025), which find that sand dredging, when framed as a flood-prevention effort, frequently increases hydrodynamic

instability rather than reducing disaster risk, especially in typhoon-prone areas like the Philippines.

The impacts identified in Santa and Caoayan, Ilocos Sur, are similar to those reported in other coastal communities worldwide affected by dredging. The shoreline retreat, associated land loss, and observed changes in sediment transport are consistent with the literature, indicating that over-exploitation of sand can disrupt natural sediment dynamics, increase erosion, and destabilize shorelines (Koehnken et al., 2020). Similarly, participants' reports of decreased fish catch and degraded mangrove habitat are consistent with findings from other coastal areas where dredging has led to declines in aquatic biodiversity and impacts on fisheries-dependent communities. The parallels that can be drawn to the Abra River suggest that the case is part of a larger environmental concern: unsustainable sediment extraction.

The results also reveal similar socio-economic and governance issues faced by other coastal communities, beyond environmental ones. Studies in fisheries-affected areas around the world have documented declines in fisheries, displacement of livelihoods, increased disaster vulnerability, and concerns about regulatory oversight. In Ilocos Sur, these challenges were experienced through a decline in fishing income, increased vulnerability to flooding and erosion, and a lack of community involvement in environmental decision-making. These parallels emphasize the importance of the local context of environmental issues in enhancing the teaching and learning of the Earth and Space Sciences and helping learners make connections between environmental issues occurring in their communities and those on a global scale (Koehnken et al., 2020; Gacu et al., 2025; Torres et al., 2025).

When these impacts are mapped to the Earth and Space Science Curriculum, the study's results reveal that all six themes can be embedded and are aligned with the Grade Level, content standards, and learning competencies. It further supports the educational theory of constructivism, in which learning is more effective and meaningful when learners are engaged in a more authentic, contextualized learning environment anchored in place-based and problem-based approaches. These theories and approaches improve student engagement, scientific understanding, environmental awareness, and problem-solving skills among learners, bridging classroom learning and community realities (Marchant et al., 2019; Rachman et al., 2021). Furthermore, place-based education supports sustainability-focused education by linking science to local environmental issues and students' experiences, thereby increasing their awareness, engagement, and competence in taking action on the environment. It is in line with the Department of Education's focus on student-centered, contextualized learning that makes learning relevant and meaningful for students (Hernandez Gonzalez, 2023)

The results of the study also informed the design and planning of learning activities, bridging the themes on the impact of sand dredging to possible classroom practice through constructivist, problem- and inquiry-based learning activities. Evidence suggests that when students engage with real environmental problems in their communities, they develop critical thinking, problem-solving, argumentation, and action skills, enabling them to build knowledge-construction skills (Baptista et al., 2025; Holley & Par, 2020). Stevenson et al. (2024) argued that sustainability education grounded in a local environmental context enhances learner participation and connects scientific understanding with community involvement.

The curriculum mapping analysis suggests that thematic integration may offer a promising approach to organizing complex, multidisciplinary environmental issues within Earth and Space Science instruction. This interpretation is based on the observed alignment between the identified themes and curriculum competencies rather than on empirical comparisons of instructional effectiveness. In parallel with the study by Drake and Reid (2020), the theme-based model enables a coherent arrangement of concepts while ensuring strong adherence to disciplinary standards, making it suitable for structured curricula such as DepEd SHS. Sinnema et al. (2023) discovered that thematic curriculum designs enhanced students' systems thinking and long-term retention of intricate Earth Science concepts.

Furthermore, this study documented environmental and socioeconomic changes observed in communities affected by sand dredging activities through field observations, stakeholder interviews, and secondary sources. However, the qualitative case study design does not allow for definitive causal attribution between dredging operations and the identified themes. Other factors, such as typhoons, natural river migration, seasonal sediment transport, coastal processes, climate-related events, and other human activities, may also contribute to the observed environmental conditions. Therefore, the findings should be interpreted as perceived and observed changes associated with dredging activities rather than conclusive evidence that dredging alone caused these changes. Future studies employing longitudinal environmental monitoring, geospatial analyses, hydrodynamic modeling, and water or sediment quality assessments are recommended to determine causal relationships better and quantify the relative contribution of dredging to environmental change.

Overall, this study demonstrates that the identified environmental changes associated with dredging activities provide an authentic integrative context for teaching Earth and Space Science by situating core scientific concepts within local environmental issues. It effectively connects scientific concepts to community realities, enhancing the relevance, significance, and social grounding of learning.

5. Conclusion

This study explored the impacts of sand dredging in the coastal communities in Santa and Caoayan, Ilocos Sur, that resulted in environmental issues, particularly coastal erosion and shoreline retreat, sediment transport and river mouth dynamics, marine biodiversity loss and ecosystem destruction, socioeconomic impacts on coastal communities, climate resilience and disaster risk, and policy and governance gaps. Beyond its contribution to Earth and Space Science instruction, the study underscores not only the significance of contextualization and place-based learning in implementing Earth and Space Science in the SHS curriculum but also the need for such educational policies. The results indicate that linking local environmental problems to the science curriculum can effectively connect the curriculum to students' lives. Curriculum developers, educational leaders and policymakers need to do more to support the creation of local educational products, teacher professional development and community-based education programs as schools become more concerned with preparing students to tackle complex environmental issues. Improving these policies can help build scientifically literate, environmentally responsible, and civically engaged students who are better able to make their own contributions to sustainable development and environmental stewardship in their local communities and globally. The locally documented environmental issues closely align with essential Earth and Space Science concepts and competencies, notably weathering, erosion, sedimentation, surface water systems, mineral resource extraction, ecosystem interactions, and disaster risk reduction. These concepts are clearly manifested in the local environment, demonstrating the relevance of Earth science principles in explaining real-world environmental problems experienced by learners and their communities.

The findings also provide a strong basis for designing contextualized learning activities within the strengthened Senior High School curriculum. Local sand dredging impacts can be used to support learning tasks that promote critical thinking, environmental literacy, and civic responsibility by engaging students in analyzing community-based environmental data and proposing evidence-based solutions. Among the curriculum integration models examined, the theme-based model appeared to offer the strongest alignment with the identified environmental themes and Earth and Space Science competencies. However, this conclusion should be viewed as an analytical recommendation derived from curriculum mapping rather than as definitive evidence of superiority. Future studies involving curriculum experts, teacher evaluations, and classroom implementation may further validate the appropriateness and effectiveness of this approach.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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