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Tidal Learning Labs: Community Knowledge, Artificial Intelligence and Coastal Climate Change Education for Sustainable Futures

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Abstract:

Climate change education has become increasingly significant because the young generation is facing the effects of rising sea levels, coastal erosion, biodiversity loss, marine pollution, extreme weather events and changing livelihoods. However, climate change is taught via textbooks and diagrams, thus the learning of the subject lacks connection between the knowledge and students' experience. The paper suggests Tidal Learning Labs, the community and technology-based educational approach that links environmental learning with coastal regions, environmental knowledge of communities, environmental data and novel digital technologies. Students, teachers, coastal communities, fishers, environmental organizations, scientists and technology platforms are brought together to form a participatory learning process. In this model, artificial intelligence is seen as an auxiliary technology that assists in interpreting data, visualizing patterns, translating information and providing learning materials rather than substituting human or community knowledge. The suggested model includes such activities as field observations, citizen science, mangrove restoration, sustainable fisheries education, marine litter monitoring, Internet of Things (IoT) sensors, satellite imagery, Artificial Intelligence (AI), Virtual Reality (VR) and Augmented Reality (AR). Six cases related to the topic are analyzed; these include school-based mangrove education program in coastal Tamil Nadu; a citizen science initiative along the coastal line by the Portuguese, the GLOBE / S'COOL partnership between NASA and the use of satellite data, UNESCO's Ocean & Climate Village, use of virtual reality for climate education, and research on indigenous ecological knowledge in Tamil Nadu fisher communities. These examples show how experience-based, participatory, technology-driven and community-oriented environmental learning can provide valuable insights in terms of

education. The paper posits that the Tidal Learning Labs could revolutionize the way the classroom turns into an ecologically engaged environment. The model is in harmony with the National Education Policy (NEP) 2020, Education for Sustainable Development (ESD), and Sustainable Development Goals (SDGs); SDG 4, SDG 13, and SDG 14, in particular.

Keywords*:* Tidal Learning Labs, Climate Education, Artificial Intelligence, Citizen Science, Ocean Literacy, Experiential Learning.

Introduction:

Climate change is not any more an issue of the environment that needs to be predicted through scientific findings. The phenomenon is felt through altered weather patterns, erosion of the coasts, floods, rising sea levels, pollution of the ocean, loss of biodiversity, and alteration of ways of living. The people living at coasts are especially vulnerable, because their social, cultural, and economic life is intertwined with marine and coastal environments. Fishing villages are a good example of communities whose life depends on the ecology directly and whose members know a lot about tides, winds, currents, behavior of fish, seasons, and coast dynamics.

For children growing up at coasts, the process of altering the environment becomes a daily one. However, the school system often disconnects the information concerning the environment from the environment where children live. Textbooks provide information about climate change, ocean pollution, mangroves, or sea-level rise, yet the students might never have an opportunity to study the process, document it, consult the local population, or take part in solving the problem.

The concept of Tidal Learning Labs is a response to the above question. It is envisaged as an adaptable learning model wherein the coast itself is used as the learning laboratory. The students study the local environmental issues, make observations, engage with the local experts, analyze scientific and digital data and think of solutions. In the model, the traditional and modern forms of knowledge are integrated instead of being considered as different.

The importance of such an approach has been reflected in the increasingly important concept of Education for Sustainable Development at the international level. UNESCO defines the Education for Sustainable Development as an approach that enhances the capacity for action in regard to the problems associated with the environment and society. It

aims at preparing the learners to deal with climate change and sustainable development through schools, curriculum, teachers, and communities. (UNESCO)

Such a model also becomes relevant in the context of the National Education Policy 2020 of India. NEP 2020 puts emphasis on holistic development, critical thinking, experiential learning, interdisciplinary learning, technology and local relevance in education. The Government of India considers experiential learning as an essential aspect of the new educational approach and encourages the use of technology in education. However, AI should not become the authority that interprets the environment. In Tidal Learning Labs, AI acts as an interpretive support, and students, teachers, scientists, and knowledge-holders from the community are the center of interpretation and decision-making process. This is especially important in coastal settings, where observations made in local ecological knowledge might be hard to express in the form of datasets.

Literature Review

Climate change education should produce not only facts but also understanding of environmental processes, critical thinking, knowledge of social consequences, and the ability to react.

In its current framework on climate education, UNESCO focuses on knowledge, skills, values, attitudes, and actions. The UNESCO's Greening Education Partnership is based on a whole system approach which includes schools, curricula, teachers' education and communities. (UNESCO)

Such an approach is especially important for the coast because environmental issues are interconnected. For example, disappearance of mangroves cannot be considered as a purely biological issue, it might have something to do with land usage, fishing, livelihoods, coastal development, pollution, climate change, etc.

Experiential learning allows tackling such complexity. NEP 2020 mentions experiential, inquiry, discovery, discussion, and analysis-based learning.

Objectives

The main objective of this paper is:

To present the proposal of Tidal Learning Labs as a model based on community experience and technological intervention for fostering children's climate literacy and engagement in the sustainability of coasts.

The objectives are:

- To bridge classroom-based education and local coastal environment/ community knowledge of children.

- To incorporate the principles of citizen science and environmental observation within climate education.
- To explore the role of AI, IoT, satellite data, VR, and AR in environmental education.
- To motivate students for coastal conservation and climate action.
- To develop the model of inter-disciplinary education in light of NEP 2020, SDG 4, SDG 13 and SDG 14.
- To highlight the educational potential of the model through case studies.

Research Method/Methodology

Conceptual and qualitative methodology is adopted in the current paper. The paper does not intend to showcase the results of Tidal Learning Labs that has been implemented in practice. Rather, the paper develops the proposed model through a review and synthesis of literature in the field of educational policies, environmental education, community knowledge, citizen science, and technology-enabled learning projects.

Case study analysis is used in this study to find practices that can be used to help develop the suggested model.

Some of the sources examined are as follows:

1. Government of India's NEP 2020;
2. UNESCO's Education for Sustainable Development;
3. UNESCO's Greening Education Partnership;
4. UNESCO's AI Competency Framework for Students;
5. Sustainable Development Goals of United Nations;
6. FAO documents on small-scale fisheries and local knowledge;
7. Research on the fishing communities of Tamil Nadu;
8. Environment-based citizen science programs;
9. Education programs for the coastal region;
10. Research on VR and immersive learning about the climate.

Findings

As Tidal Learning Labs is a proposed model, the findings provided below are theoretical findings based on the literature and case studies.

The analysis of the literature and the case studies shows the following six main findings.

Finding 1: The local environment can act as an extended classroom.

Students can benefit from the study of climate science if the concepts of the environment are related to something familiar to them.

Finding 2: Community knowledge can enhance climate education.

Local people such as the coastal fishers and others can contribute to the education through their ecological knowledge based on environmental observations made throughout their lives.

Finding 3: Technology allows bridging local and global environmental levels.

IoT sensors allow collecting local-level information while satellite imagery shows bigger geographic patterns.

Finding 4: AI can help with interpretation but cannot substitute human decision-making.

AI can help with information organization, pattern detection, visualization, translation, and learning support; however, environmental decisions must be interpreted by people.

Finding 5: Immersive learning makes climate futures more comprehensible.

Virtual reality and augmented reality can help students understand environmental change that is hard to experience firsthand.

Discussion:

Tidal Learning Lab Model.The key idea of this paper is that a classroom becomes a Tidal Learning Lab if it connects four knowledge systems:

- Community knowledge
- Scientific knowledge
- Student observation
- Digital and technological knowledge

These four knowledge systems do not exist separately.

Figure 1. Proposed Tidal Learning Lab Learning Cycle

LOCAL ENVIRONMENT
↓
COMMUNITY KNOWLEDGE
↓
STUDENT OBSERVATION
↓
CITIZEN-SCIENCE DATA
↓
IoT + SATELLITE DATA
↓
AI-SUPPORTED ANALYSIS
↓
VR / AR VISUALISATION
↓

STUDENT DISCUSSION AND CRITICAL REFLECTION
↓
COMMUNITY ACTION
↓
ECOLOGICAL LEARNING

Then the cycle goes back to the environment. Thus, the process is not limited to one classroom event, but a continuous cycle.

Conclusion:

Tidal Learning Labs offers an innovative way of thinking about climate education, wherein the environment becomes the classroom and the community becomes the partner in creating the knowledge. It answers one of the biggest weaknesses of traditional climate education: the disconnect between environmental data and people's actual experience of the environment.

The case studies show that some elements of the suggested model have been developed independently. School based mangroves programs in Tamil Nadu prove the benefits of field-based ecological learning. A citizen-science program in Portugal shows the educational benefits of students' participation in coastal environment monitoring. GLOBE/S'COOL program illustrates how student observations can link with satellite science. Ocean & Climate Village by UNESCO exemplifies the prospects for immersive ocean education.

Climate education using VR illustrates the power of experiential digital environments. Research on fishers of Tamil Nadu highlights the significance of local ecological knowledge. (IUCN Engage)

The strength of Tidal Learning Labs lies in its ability to integrate all these aspects within one framework for education.

The underlying principle is clear:

Students must not only learn about environmental changes; they have to see it, hear about it from those affected, research it, interpret the evidence, and get involved in solving the problem.

AI can support this process in helping students analyse and visualize environmental data. Nevertheless, AI should never become the source of knowledge but just an instrument in gaining insights into the problem.

This approach is consistent with the educational paradigm established by NEP 2020 and focused on experiential, interdisciplinary, holistic, and technology-enabled learning. (PM India)

At the international level, it helps reach SDG 4 with sustainability education, SDG 13 with climate awareness and resilience, and SDG 14 with ocean and coastal education. (Sustainable Development Goals)

Therefore, Tidal Learning Labs can transform the classroom from a space where climate change is merely discussed into a space where environmental knowledge is experienced, questioned, produced, shared, and applied.

Limitations:

The proposed Tidal Learning Labs model has some limitations. First, the framework has not yet been implemented and tested through a large-scale school-based intervention. Therefore, its educational effectiveness cannot yet be statistically confirmed. Second, access to AI tools, VR equipment, IoT sensors, satellite data, and reliable internet may differ between schools. Third, teachers may require additional training to use environmental technologies responsibly. Fourth, community knowledge must be collected ethically, with respect for privacy, ownership, and cultural practices. Finally, AI-generated information may contain errors or bias, so student interpretations should always be checked against reliable scientific evidence and community knowledge.

Recommendations

Pilot Tidal Learning Labs in selected coastal schools before wider implementation.

Begin with low-cost activities such as environmental observation, field journals, interviews, biodiversity mapping, and marine-litter surveys before introducing advanced technologies.

Train teachers in climate education, citizen science, AI literacy, and environmental ethics.

Include fishers and coastal community members as knowledge partners rather than treating them merely as research subjects.

Use AI critically, requiring students to verify AI-generated information.

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