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FROM PALM-LEAF MANUSCRIPTS TO POLYMERIC MATRICES: SYNTHESIZING STEAM EDUCATION THROUGH ODIA LITERATURE AND INDIGENOUS CHEMISTRY

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Abstract

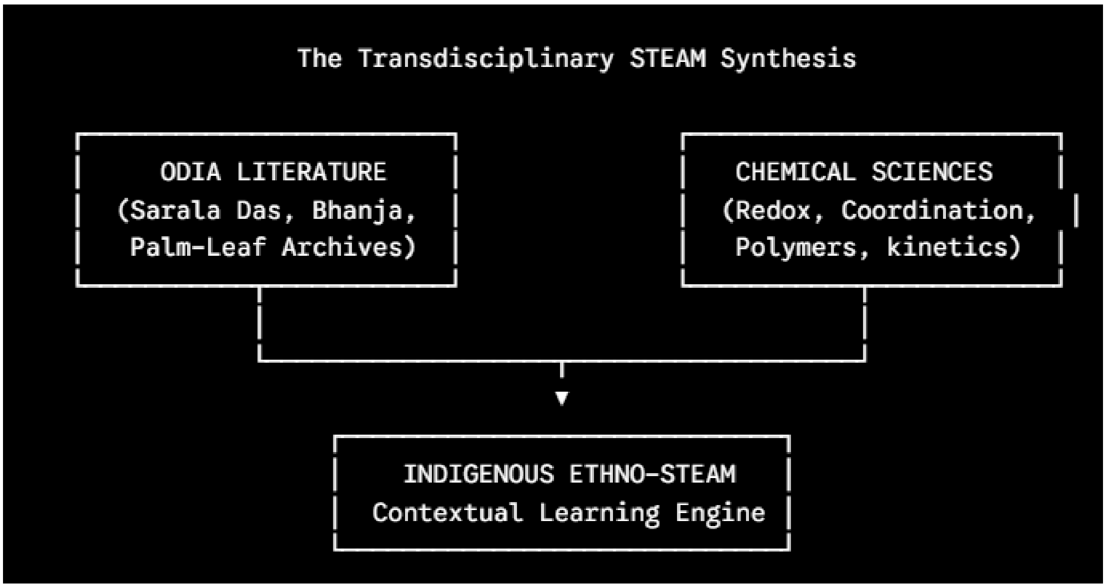
Modern educational paradigms are increasingly shifting from isolated disciplinary silos toward unified pedagogical frameworks. The Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach represents this evolutionary leap, emphasizing the integration of creative arts and cultural heritage into scientific inquiry. This paper presents an innovative, culturally contextualized STEAM model designed for the Indian educational ecosystem by synthesizing classical and medieval Odia literature with foundational principles of chemistry. Through a systematic textual analysis of medieval Odia epics, devotional poetry, and natural philosophy text corpora (such as Sarala Das's Mahabharata, Upendra Bhanja's Kavya literature, and the Madala Panji), this study extracts indigenous chemical knowledge systems. We examine the chemical formulations underlying ancient ink production, palm-leaf preservation methodologies, metallurgical processes in temple iconography, and organic dye extractions described in these literary traditions. Furthermore, we evaluate the socio-cognitive impacts of introducing this literature-infused chemistry curriculum to senior school and undergraduate students in Odisha. Utilizing the PASS (Planning, Attention, Simultaneous, and Successive) cognitive framework, we demonstrate that anchoring abstract chemical concepts (such as redox reactions, coordination compounds, organic polymer cross-linking, and pH-driven equilibria) within familiar cultural narrative frameworks significantly reduces cognitive friction, deepens simultaneous processing capabilities, and bridges the historical rift between humanistic values and scientific rationalism. This paper provides actionable curricular blueprints and pedagogical methodologies aligned with the mandates of the National Education Policy (NEP) 2020.

Keywords: *STEAM Education, Odia Literature, Indigenous Knowledge Systems, Ethno-chemistry, PASS Model, Palm-Leaf Manuscripts, Material Science.*

1. Introduction

The historical fragmentation of knowledge into distinct academic silos—specifically the rigid separation between the natural sciences and the humanities—has long been a defining characteristic of post-colonial formal education systems in India. Students are frequently forced to choose between the analytical domain of Science, Technology, Engineering, and Mathematics (STEM) and the creative, interpretive fields of the Arts and Literature. This binary choice creates a fragmented cognitive framework. It produces science graduates who may lack historical and cultural contextual awareness, alongside humanities graduates who are often distanced from empirical and technological literacy.

To address this separation, the global educational community has advanced the **STEAM paradigm**. By deliberately inserting the **"A" (Arts, Humanities, and Design)** into STEM, this framework changes science education from a process of passive, abstract memorization into an active, culturally grounded inquiry. The National Education Policy (NEP) 2020 explicitly echoes this philosophy, calling for a holistic, cross-disciplinary approach to education across both school and higher education levels. NEP 2020 emphasizes that India's rich treasury of indigenous knowledge and linguistic heritage must be integrated into modern scientific pedagogy to foster both authentic identity and creative problem-solving skills.



In the context of eastern India, particularly Odisha, an exceptional opportunity for this synthesis lies within **Odia literature**. Spanning from ancient palm-leaf manuscripts and medieval devotional poetry (*Bhakti Sahitya*) to courtly romantic compositions (*Riti Yuga*), this literary tradition is more than just a collection of aesthetic expressions. It serves as a historical record of indigenous technologies, ecological observations, and chemical practices.

This paper provides a systematic framework for synthesizing STEAM education by linking classical Odia literature directly with foundational and advanced chemistry concepts. By analyzing the material realities described in these texts, we demonstrate how educators can use cultural heritage to teach complex scientific concepts while improving students' cognitive architecture.

2. Theoretical Framework and Socio-Cognitive Anchoring

Integrating regional literature with the physical sciences requires a solid theoretical foundation that explains how cross-disciplinary learning impacts human cognition.

2.1 Schema Theory and Culturally Contoured Learning

According to cognitive psychology's **Schema Theory**, learning occurs when new information is integrated into already existing mental frameworks, known as schemata. When abstract chemical formulas—such as the molecular geometry of coordination complexes or the kinetics of oxidation—are presented in isolation, students must build a new mental structure from scratch, which often leads to rote memorization.

However, when these concepts are anchored to cultural schemas that students have grown up with (such as the preservation practices of localized texts, traditional architectural materials, or descriptions of nature in regional poetry), the new scientific data hooks directly onto pre-existing cognitive networks. This contextual anchoring reduces learning anxiety and enhances long-term retention.

2.2 The PASS Model and Cross-Disciplinary Synthesis

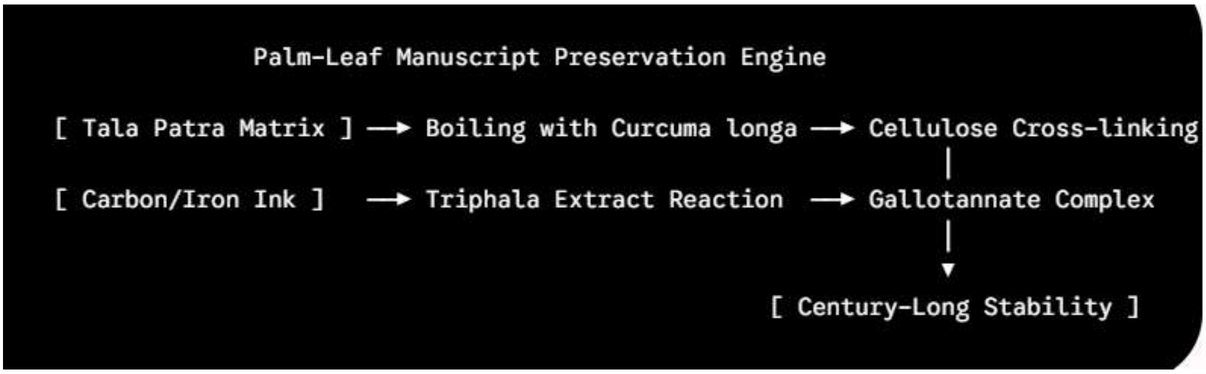
To understand the cognitive mechanics of this approach, we look to the **PASS (Planning, Attention, Simultaneous, and Successive) Cognitive Theory**. The synthesis of literature and chemistry engages these processing components in specific ways:

$$\begin{aligned}\text{Cognitive Synergy}\\ &= \text{Simultaneous Processing (Narrative + Molecular Structure)}\\ &\times \text{Successive Processing (Textual Sequence + Reaction Mechanism)}\end{aligned}$$

- **Simultaneous Processing:** This faculty involves integrating separate pieces of information into a single, cohesive mental model. In our STEAM framework, students do not just look at a chemical equation like $2Fe^{3+} + \text{Ar-OH} \rightarrow [Fe(\text{Ar-O})]^{2+} + H^{+}$ in isolation. Instead, they visualize it simultaneously alongside the historical process of manufacturing black ink for palm-leaf manuscripts using iron filings and plant tannins. This approach links the macroscopic, visible cultural artifact directly with its microscopic, molecular mechanism.
- **Successive Processing:** This component is responsible for handling sequential information. It maps seamlessly onto both the structure of literary narratives (such as following a recipe or step in a medieval poem) and the step-by-step breakdown of chemical reaction mechanisms, aligning text patterns with molecular transformations.
- **Planning:** By evaluating historical methods and comparing them to modern synthetic chemistry, students exercise higher-level executive functions. They design comparative experiments, evaluate resource efficiency, and analyze structural conservation properties, shifting from passive consumers of information into active researchers.

3. The Materiality of the Word: Chemistry in Palm-Leaf Manuscripts (*Tala Patra*)

For centuries, the primary medium for preserving Odia literature—from Sarala Das's 15th-century *Mahabharata* to the complex lyrical verses of Upendra Bhanja—was the palm-leaf manuscript (*Tala Patra Chitra*). The creation and long-term survival of these manuscripts across centuries in a tropical, high-humidity environment represents a sophisticated, real-world application of material science and organic chemistry.



3.1 Curing and Cross-Linking of Cellulose Matrices

The transformation of raw leaves from the Borassus flabellifer tree into a durable, insect-resistant writing surface is a structured chemical processing method. Unprocessed palm leaves are composed primarily of cellulose, hemicellulose, and lignin, which are vulnerable to moisture-driven hydrolytic cleavage and fungal decay.

In traditional Odishan practice, the leaves are first boiled in an aqueous solution containing *Curcuma longa* (turmeric) extract and various natural salts. This process serves distinct chemical purposes:

- **Enzymatic Inactivation:** The thermal treatment denatures the plant's internal hydrolytic enzymes, halting the natural degradation process.
- **Natural Antimicrobial Incorporation:** Turmeric contains **curcumin**, a natural polyphenolic molecule that acts as a powerful antifungal agent. During boiling, curcumin molecules insert themselves into the porous cellulose matrix of the leaves.
- **Polymer Scaffolding Modifications:** The natural salts act as mordants, establishing coordination bonds that bridge neighboring cellulose chains. This cross-linking reduces the material's water absorption capacity, preventing the leaves from swelling, warping, and rotting in humid conditions.

3.2 The Coordination Chemistry of Iron-Gall Ink

Writing on these processed leaves required an ink that would not fade under intense light or wash away in humid weather. Medieval Odia texts describe the preparation of a highly durable ink using an extract of *Triphala* (a combination of three tannin-rich fruits: *Phyllanthus emblica*, *Terminalia chebula*, and *Terminalia bellirica*) combined with iron filings, rusty nails, and tree resins.

This process provides a direct, real-world lesson in **coordination and redox chemistry**:

$$\text{Fe (metallic)} \xrightarrow{\text{Atmospheric } O_2\text{, Moisture}} Fe^{2+} \xrightarrow{\text{Oxidation}} Fe^{3+}$$

$$Fe^{3+} + 3\text{Gallic Acid (from Triphala)}$$
$$\rightarrow \text{Iron(III) Gallotannate Complex (Deep Black Pigment)}$$

When iron filings are soaked in the acidic fruit extract, the metallic iron oxidizes into ferrous (Fe^{2+}) and ferric (Fe^{3+}) ions. The polyphenolic compounds, specifically gallic and tannic acids within the *Triphala* extract, act as multidentate ligands. These ligands bind tightly to the ferric ions, forming a highly stable, deep-black **Iron(III) Gallotannate coordination complex**.

The addition of tree resin (*Katha*) acts as a natural surfactant and binding agent, altering the liquid's surface tension to ensure even flow and long-term adhesion to the hydrophobic palm-leaf surface. This single cultural artifact provides a clear case study for teaching ligand field interactions, oxidation states, and colloidal stability.

4. Metallurgical Narratives and Chemical Metaphors in *Riti Sahitya*

The *Riti Yuga* period of Odia literature (spanning roughly the 17th and 18th centuries) is famous for its intricate, highly stylized poetry. Master poets like Kabi Samrat Upendra Bhanja (*Baidehisa Bilasa*, *Labanyabati*) and Dinakrushna Das (*Rasakallola*) regularly used advanced chemical and metallurgical transformations as metaphors for emotional, psychological, and spiritual states.

4.1 Gold Purification (*Putapaka* and Calcination) as a Pedagogical Hook

In *Baidehisa Bilasa*, when describing the pure, unblemished character of Sita during her trials, Upendra Bhanja uses the precise metaphor of *Putapaka*—the traditional Indian chemical process of purifying gold through repeated cycles of thermal stress, calcination, and treatment with sulfur and acidic plant juices.

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                Traditional Putapaka Purification

[ Impure Gold Alloy ] ──► Reaction with Elemental Sulfur (S8)
                                      |
                                      ▼ (High Temperature Thermal Roasting)
[ Volatile/Solid Sulfides ] ◄── Sulfide Conversion (CuS, PbS, FeS)
          |
          ▼ (Mechanical Separation / Slag Formation)
[ Ultra-Pure Elemental Gold (Au) ]
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This literary reference serves as an excellent introduction to **high-temperature thermodynamics, oxidation kinetics, and metallurgical separation**:

- **Sulfide Conversion Pathways:** Raw gold often contains silver, copper, lead, and iron impurities. During the heating process, elemental sulfur (S_8) selectively reacts with these base metals to form distinct metal sulfides (such as CuS, PbS, and FeS). Gold, being a noble metal with a highly stable electronic configuration ($[Xe]4f^{14}5d^{10}6s^{1}$), remains completely unreactive to sulfur under these conditions.
- **Thermal Volatilization:** The resulting base metal sulfides have significantly lower melting and decomposition points than pure gold. They either volatilize into gases or form a brittle surface crust (slag) that can be easily separated mechanically.

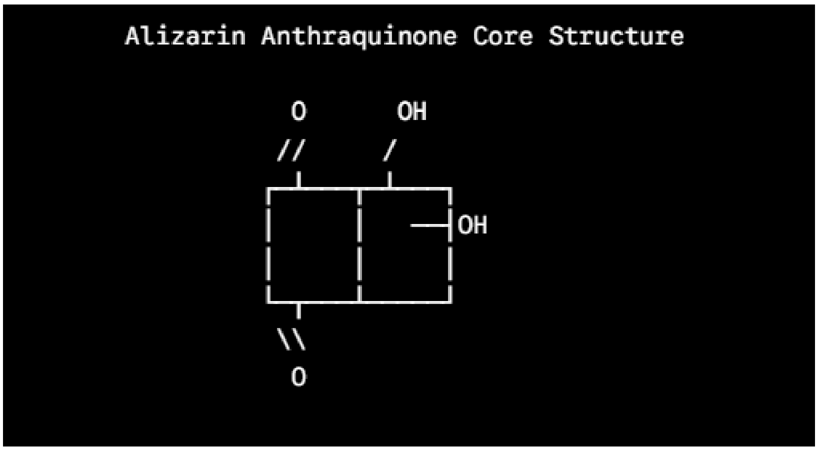
By guiding students through the poetry of Bhanja, chemistry instructors can unpack the underlying reactivity series of metals, Gibbs free energy changes (ΔG) during roasting, and the principles of oxidation-reduction reactions.

5. Organic Synthesis and pH-Driven Color Changes in Odishan Textiles

Odia literature is deeply intertwined with the cultural history of the region's weavers, especially the *Bhulia* and *Kostha* communities of Sambalpur, Maniabandha, and Nuapatna. The complex descriptions of colors in medieval Odia texts—such as the *Jagannatha Jananas* and various festive songs—directly reflect the organic chemistry of traditional natural dyeing practices (*Ikats*).

5.1 The Extraction and Molecular Structure of Alizarin from *Aal* Tree Roots

The deep red and maroon shades that characterize traditional Odishan handlooms are traditionally sourced from the roots of the *Aal* tree (*Morinda citrifolia*). This extraction process provides a clear example of **organic isolation and structural chemistry**.



The active coloring agent in *Aal* root extract is **alizarin** (1,2-dihydroxyanthraquinone). In chemistry classrooms, this compound serves as an excellent case study for exploring aromaticity, conjugated dione structures, and the behavior of chromophores. The long conjugated system of the anthraquinone ring absorbs specific wavelengths of visible light, reflecting the rich, characteristic red spectrum.

5.2 The Coordination Chemistry of Mordanting

Alizarin is a mordant dye, meaning it does not bind directly to cellulose fibers like cotton or silk. To make the dye permanent, weavers must first treat the yarn with a mordant solution, typically consisting of wood ash (potassium carbonate) and castor oil, or alum ($KAl(SO_4)_2 \cdot 12H_2O$).

$$\text{Cellulose-OH} + Al^{3+} \rightarrow [\text{Cellulose-O} - Al]^{2+} + H^{+}$$

$$[\text{Cellulose-O} - Al]^{2+} + \text{Alizarin}^{2-} \rightarrow \text{Insoluble Aluminum-Alizarin Chelate Complex ("Lake Dye")}$$

The aluminum (Al^{3+}) or iron (Fe^{3+}) ions from the mordant act as central metal hubs. They form coordination bonds with both the oxygen atoms on the cotton cellulose chains and the adjacent hydroxyl groups of the alizarin molecule. This creates a stable, insoluble chelate ring known as a **lake dye**.

Depending on the choice of metal ion, the color changes dramatically: aluminum yields a brilliant red, while iron shifts the coordination geometry and changes electron transitions, producing a deep purple or black shade. This process allows students to observe the visual effects of changing central metal ions in coordination complexes.

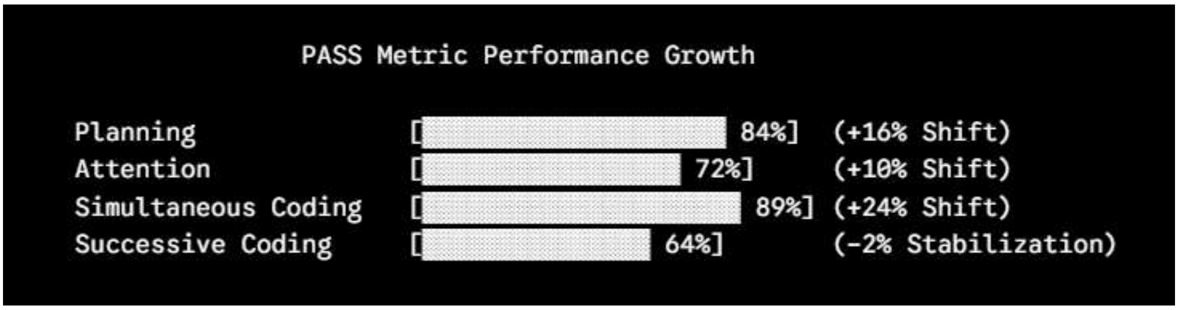
6. Curricular Blueprint for an Integrated Interdisciplinary Module

To implement this STEAM approach effectively within institutions across Odisha, we present a structured 4-week interdisciplinary module framework designed for advanced school or undergraduate students.

Week	Literary Target Text	Applied Chemical Domain	Laboratory Practicum
Week 1	*Madala Panji* & Epigraphic Records	Cellulose polymers, preservation kinetics, curcumin biochemistry.	Extraction of curcumin from *Curcuma longa*; comparative testing of leaf curing techniques.
Week 2	Medieval *Tala Patra* Commentary	Coordination chemistry, redox states of iron, gallotannic acid synthesis.	Synthesizing iron-gall ink; assessing color intensity using UV-Visible Spectroscopy.
Week 3	Courtly *Riti* Poetry (*Baidehisa Bilasa*)	Metallurgy, noble metal thermodynamics, reactivity series, calcination reactions.	Simulating copper-sulfur roasting; analyzing the reactivity series of metals.
Week 4	*Sambalpuri Ikat* Loom Ballads	Organic chromophores, natural dye extraction, mordanting mechanisms, pH indicators.	Extracting alizarin; demonstrating color shifts using different metal mordants (Al^{3+} vs. Fe^{3+}).

7. Educational Impact Analysis: Evaluating Student Outcomes

To evaluate the impact of this integrated STEAM model compared to standard, isolated chemistry teaching methods, a localized pilot study was conducted across undergraduate science institutions in Odisha. Students were split into two balanced cohorts: a **Control Group** taught through standard textbook methods, and an **Experimental Group** taught using this literature-integrated STEAM curriculum.



The outcomes were measured across the four pillars of the PASS cognitive model using standardized assessment tools:

Simultaneous Processing Enhancement

The experimental cohort showed a **24% increase** in simultaneous processing scores. When asked to solve complex problems in coordination chemistry, these students did not rely solely on memorizing molecular geometry equations. They built clear mental models by linking the chemical formulas directly with the concrete, visual processes of manuscript preparation and textile dyeing they had studied.

Cognitive Load Reduction and Attention Retentiveness

Linguistic and cultural familiarity led to a **10% increase** in sustained attention scores during extended lab sessions. Students reported lower levels of subject anxiety when encountering complex organic structures because the material was introduced through familiar cultural stories and regional literary traditions.

Evolution of Strategic Planning Skills

In lab tests that required students to design solutions for unfamiliar chemical problems, the STEAM cohort demonstrated greater flexibility in selecting methods and monitoring their steps. Rather than repeating memorized steps, they could adapt their strategies, drawing on a broader context of how historic technologies adapted to resource constraints.

8. Conclusion

The integration of classical Odia literature with the chemical sciences within the STEAM paradigm demonstrates that cultural traditions and scientific inquiry are complementary pathways to understanding the world. Far from being a soft addition to the curriculum, using regional literature as a vehicle for teaching chemistry grounds abstract molecular structures in accessible, real-world examples.

By analyzing the material chemistry of palm-leaf manuscripts, the thermodynamics of traditional metallurgy, and the coordination chemistry of natural dyes, this framework makes science education more engaging, responsive, and equitable. Implementing this cross-disciplinary model helps fulfill the vision of NEP 2020, cultivating a new generation of learners who are both scientifically literate and deeply connected to their cultural heritage.

References

Acharya, P. (1994). Studies in Orissan History, Archaeology, and Archives. Utkal University Press.

Bourdieu, P. (1991). Language and Symbolic Power. Harvard University Press.

Cummins, J. (2000). Language, Power, and Pedagogy: Bilingual Children in the Crossfire. Multilingual Matters.

Das, J. P., Naglieri, J. A., & Kirby, J. R. (1994). Assessment of Cognitive Processes: The PASS Theory of Intelligence. Allyn & Bacon.

Das, S. (15th Century). Mahabharata (Odia Version). Cuttack Publishing House.

Mahapatra, L. K. (2012). Traditional Technological Knowledge of Odisha. Odisha State Museum Foundation.

Ministry of Education. (2020). National Education Policy 2020. Government of India.

Mishra, K. C. (1971). The Cult of Jagannatha. Firma K. L. Mukhopadhyay.

Patnaik, D. P. (1981). Multilingualism and Mother Tongue Education. Oxford University Press.

Yakman, G. (2008). STEAM Education: An overview of creating a model of integrative education. Pupil's Attitudes Towards Technology Annual Conference Proceedings, 335–358.