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Decentralized Approach to Ontology Development for Improved Knowledge Sharing and Reuse: Evidence and Implications from Rivers State, Nigeria

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Abstract
Ontology development has traditionally relied on centralized frameworks, which impose significant constraints on scalability, collaborative participation, and adaptability within dynamic, distributed knowledge environments. This study examines decentralized approaches to ontology engineering as a viable alternative to conventional methodologies, with a focus on enhancing knowledge sharing and reuse across heterogeneous systems in Rivers State, Nigeria. Through a systematic literature review guided by the PRISMA framework, this paper analyses the limitations of centralized ontology development paradigms, evaluates enabling technologies, including blockchain, InterPlanetary File System (IPFS), and distributed ledger technologies, and synthesizes current models of decentralized ontology engineering. The study further appraises the applicability of these approaches within Rivers State, where rapid urbanization, oil-and-gas sector digitization, agricultural transformation, and e-governance initiatives generate rich but organizationally fragmented domain knowledge. Findings indicate that decentralized frameworks offer substantial advantages in transparency, semantic provenance, community-driven governance, and real-time collaborative updates; however, challenges persist in semantic consistency, version control, and tooling support. A four-layer conceptual framework for decentralized ontology development is proposed, and priority areas for future empirical research and deployment are identified, with specific reference to the Rivers State context..

Keywords: Ontology Engineering; Decentralized Systems; Semantic Web; Knowledge Sharing; Knowledge Reuse

Introduction

The exponential growth of data generated through individual, institutional, and machine-based activities has intensified the demand for robust mechanisms of semantic interoperability and knowledge reuse across heterogeneous systems. In Rivers State, Nigeria, a region characterized by a dynamic oil-and-gas economy, a diverse linguistic heritage comprising over forty ethnic groups, a rapidly expanding health sector, and an emergent e-governance agenda, the need for scalable knowledge management infrastructures has become especially acute. Ontology, formally defined as a shared specification of a conceptualization (Gruber, 1995), has emerged as a foundational technology for enabling machines and humans to interact meaningfully with complex, distributed knowledge structures. The theoretical basis of ontology engineering derives from formal ontology in philosophy, which was adapted for knowledge representation in computer science by Guarino (1995) and operationalized for knowledge sharing by Gruber (1995). Gruber's seminal definition establishes three core epistemic commitments underpinning ontological systems: shared understanding, formal specification, and conceptual abstraction. These commitments collectively enable disparate computational systems to achieve semantic interoperability, a condition of particular importance in multi-institutional environments such as the Rivers State Government's digital transformation initiatives.

Despite their demonstrated utility, traditional ontology development processes remain predominantly centralized, governed by singular authorities or small expert consortia. This architecture imposes significant limitations on scalability, responsiveness, and collaborative inclusivity, particularly in contexts marked by geographic dispersion and institutional heterogeneity (Souri et al., 2020). Established methodologies for ontology engineering, including METHONTOLOGY (Fernández-López et al., 1997) and the Ontology Development 101 guide (Noy & McGuinness, 2001), have provided structured, authoritative processes for building domain ontologies. These frameworks prioritize consistency and expert validation, making them effective in stable, well-bounded domains. However, their centralized governance model creates significant bottlenecks in scalability, cross-domain integration, and responsiveness to evolving knowledge. A systematic review by Souri et al. (2020) confirms that centralized approaches are increasingly incompatible with the collaborative demands of modern distributed knowledge systems. Guarino's (1995) formal ontology framework further distinguishes between top-level ontologies, which represent general concepts independent of domain, and domain ontologies, which represent knowledge specific to a particular field; this distinction provides the theoretical architecture for modular, scalable ontology engineering that informs contemporary decentralized approaches (Keet, 2021). In the Rivers State context, top-level ontologies may serve as interoperability bridges across the oil sector, health, and agriculture, while domain ontologies capture the specific terminologies of each sector.

A major challenge in achieving semantic interoperability in such settings is the difficulty of aligning heterogeneous ontologies across domains, which often leads to ambiguity and loss of meaning in data exchange (Zhou et al., 2023). In Rivers State, sectoral silos across agriculture, petroleum, health, and education perpetuate fragmented knowledge systems that are ill-served by centralized ontological approaches. Notwithstanding theoretical progress, no standardized framework exists for implementing decentralized ontology systems that simultaneously satisfy requirements of semantic integrity, security, scalability, and interoperability (Chatterjee et al., 2021). The absence of validated governance models and practical deployment cases, particularly in developing regions, constrains real-world adoption and inhibits the evolution of participatory knowledge systems. The Rivers State context exemplifies this challenge concretely: the Rivers State University Teaching Hospital (RSUTH), the Rivers State Agricultural Development Programme (ADP), and the Rivers State Ministry of Finance each operate knowledge management systems that lack interoperability, resulting in duplicated efforts and suboptimal policy outcomes.

Empirical and theoretical scholarship increasingly supports the adoption of decentralized methodologies in ontology engineering. Technologies such as blockchain, peer-to-peer networks, and distributed ledger systems have demonstrated the capacity to support collaborative ontology construction without reliance on a central authority (Hasnain et al., 2017; Zhang et al., 2022). The theoretical basis for decentralized ontology engineering draws on distributed systems theory, which posits that computational tasks can be distributed across a network of autonomous nodes without a central coordinator. Lamport's (1978) foundational work on distributed systems established principles of consensus, fault tolerance, and asynchronous communication that are directly applicable to decentralized ontology governance. More recently, blockchain theory has formalized these principles into verifiable, tamper-resistant ledger systems, enabling decentralized consensus without trusted intermediaries (Zhang et al., 2022). The application of these principles to ontology engineering represents a theoretically coherent extension of distributed systems theory into the knowledge management domain.

In response to the limitations of centralized models, decentralized methodologies have been advanced through frameworks such as NeON and the DILIGENT approach, which promote modular, network-based ontology construction and community-driven evolution (Keet, 2021; Alfaifi, 2022). These models enable multiple autonomous agents to collaboratively build, validate, and revise ontologies, distributing governance authority across contributors. Key enabling technologies include blockchain, which provides immutability, provenance tracking, and distributed consensus (Zhang et al., 2022); the InterPlanetary File System (IPFS), which facilitates content-addressed decentralized storage and eliminates single points of failure while ensuring persistent ontology versioning, a property of significant value in resource-constrained environments where server infrastructure may be unreliable, a condition encountered in rural Rivers State communities such as Ogba-Egbema-Ndoni Local Government Area; and distributed ledger technologies that enable transparent, tamper-resistant record-keeping. Hasnain et al. (2017) and Konys and Drążek (2020) further demonstrate the utility of community-curated, reusable ontologies within decentralized platforms for enhancing adaptability and inclusivity in knowledge representation.

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Yang et al. (2019) provide a comprehensive state-of-the-art review of ontology-based systems engineering, identifying governance challenges and authority bias as systemic limitations of centralized approaches. Their findings resonate strongly with the multi-institutional landscape of Rivers State, where competing governmental, private-sector, and civil-society stakeholders must negotiate shared knowledge representations without a single authoritative arbiter. Permissioned blockchain architectures, such as Hyperledger Fabric, are particularly suited to institutional environments where identity management is required, making them applicable to Rivers State government agencies. The combined use of blockchain for governance and IPFS for storage represents the most technically mature integration pathway identified in the literature, and is directly applicable to the Rivers State e-governance infrastructure currently being developed under the Rivers State Government's Digital Economy Initiative.

The Nigerian ontology engineering landscape is emerging but largely centralized and sector-specific. Egba (2022) applied semantic data structures to improve e-governance interoperability at the Federal College of Education (Technical), Omoku, an institution located in Ogba-Egbema-Ndoni Local Government Area of Rivers State, demonstrating the feasibility of ontological approaches within the state's educational sector. The study confirmed that ontology-based knowledge representation reduced data redundancy and improved retrieval efficiency by approximately 38%, providing direct empirical evidence of ontological utility in the Rivers State context. Eze et al. (2021) demonstrated the value of collaborative ontological frameworks in health information management across Nigerian tertiary institutions, findings that have direct implications for RSUTH and the Rivers State Primary Health Care Management Board.

Agricultural knowledge sharing between smallholder farmers and extension workers in the Niger Delta region has been advanced through decentralized ontology proposals by Oladimeji and Ojo (2020), whose framework identifies cassava, yam, and plantain production systems, staple crops in Rivers State, as priority domains for ontological representation. Cultural and linguistic domains have also been addressed: Ebietomere et al. (2019) built an ontology for Nigerian tribes and languages that includes Ijaw, Ikwerre, and Ogoni, three of the major ethnolinguistic groups in Rivers State, while Dahiru and Lawan (2023) developed Nija-Onto for Nigerian language documentation using Methontology and Protégé. These studies collectively affirm the growing relevance of ontological systems in Rivers State's digital transformation agenda, while also highlighting the need for more scalable and inclusive frameworks.

Adebayo and Musa (2021) examined decentralized knowledge systems in Nigerian universities and found that peer-to-peer knowledge sharing platforms reduced information latency by 45% compared to centralized repositories. Zhou et al. (2023) further substantiated the semantic interoperability challenges inherent in heterogeneous systems, providing a theoretical frame that explains the fragmentation observed across Rivers State's institutional knowledge landscape. Across all identified frameworks, however, significant limitations persist: semantic alignment across independently constructed ontological modules, consistency maintenance without centralized oversight, and tooling support for distributed collaboration remain methodologically unresolved (Gruber, 1995; Chatterjee et al., 2021). Crucially, none of the reviewed frameworks has been empirically validated in a sub-Saharan African context, representing a critical gap that the present study seeks to address.

The foregoing review reveals a convergent body of evidence establishing that centralized ontology development frameworks, while foundational to the discipline, are structurally inadequate for the dynamic, distributed, and collaborative demands of contemporary knowledge engineering. Decentralized approaches, enabled by blockchain, IPFS, and distributed ledger technologies, offer a credible and theoretically robust alternative. Yet, the field lacks a validated, context-sensitive framework for implementing such systems in developing-country settings, where rapid urbanization, sectoral fragmentation, and infrastructure constraints impose unique demands. Rivers State, with its rich but organizationally fragmented knowledge landscape spanning petroleum, health, agriculture, language, and governance sectors, provides a compelling and analytically rich context for advancing both theory and practice in decentralized ontology engineering. Studies in Nigerian domains confirm that domain knowledge is increasingly rich but organizationally fragmented (Oladimeji & Ojo, 2020; Eze et al., 2021; Egba, 2022), and the Rivers State context exemplifies the need for scalable, participatory solutions that existing frameworks do not adequately provide.

This study aims to examine decentralized approaches to ontology engineering as a viable and context-sensitive alternative to conventional centralized methodologies, with a focus on enhancing knowledge sharing and reuse across heterogeneous systems in Rivers State, Nigeria. Guided by this overarching aim, the study pursues the following

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specific objectives: (i) to examine the structural limitations of centralized ontology development with respect to knowledge sharing and reuse; (ii) to evaluate decentralized enabling technologies, including blockchain, IPFS, and distributed ledger systems, that support distributed ontology engineering; (iii) to synthesize and critically analyse existing models and frameworks for decentralized ontology development; and (iv) to propose a conceptual framework for decentralized ontology engineering applicable to developing-country contexts, with particular and empirical reference to Rivers State, Nigeria.

Materials and Methods

Research Design

This study adopts a systematic literature review (SLR) methodology, guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. The SLR approach was selected to provide a replicable, transparent synthesis of existing scholarship on decentralized ontology development, its enabling technologies, and its application contexts. The systematic review is supplemented by a contextual analysis of the Rivers State knowledge management landscape, drawing on publicly available institutional documents from the Rivers State Government, the Rivers State University, and sector-specific agencies.

Search Strategy and Source Selection

Literature was retrieved from five major academic databases: Scopus, Web of Science, IEEE Xplore, ACM Digital Library, and Google Scholar. Search terms included combinations of: “ontology development,” “decentralized ontology,” “blockchain AND ontology,” “semantic web AND knowledge sharing,” “distributed knowledge systems,” “ontology engineering Nigeria,” and “Rivers State knowledge management.” The search was limited to peer-reviewed journal articles, conference proceedings, and technical reports published between 2001 and 2024, with emphasis on sources from 2017 onwards to ensure currency. Forward and backward citation chaining was employed to identify additional relevant sources not captured in the initial database search.

Inclusion and Exclusion Criteria

Studies were included if they: (i) addressed ontology development methodologies or frameworks; (ii) examined decentralized, distributed, or blockchain-based ontology systems; (iii) reported empirical or conceptual findings on knowledge sharing or reuse; or (iv) documented ontology applications in developing-country contexts, particularly Nigeria or Rivers State. Studies were excluded if they were non-peer-reviewed, lacked sufficient methodological detail, or were duplicates of reviewed sources. A total of 47 sources were initially identified; after screening for relevance and quality using PRISMA criteria, 25 were retained for synthesis (Table 3).

Table 3: PRISMA-guided Search and Screening Summary

Stage	Criteria/Action	No. of Records	Source
Identification	Database search (2001–2024)	47	Scopus, WoS, IEEE, ACM, Google Scholar
Screening	Title/abstract review for relevance	35	All databases
Eligibility	Full-text review; peer-reviewed only	28	All databases
Included	Retained for synthesis after quality check	25	All databases

Source: Authors' PRISMA-guided review process (2024)

Analytical Framework

Retained literature was analysed using thematic synthesis, wherein recurring themes, contradictions, and research gaps were identified and organized. Analysis was structured around four thematic dimensions: (1) limitations of centralized paradigms; (2) decentralized enabling technologies; (3) existing decentralized frameworks and their performance; and

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(4) application contexts and implementation challenges, with particular attention to the Rivers State setting. Contextual analysis employed a SWOT (Strengths, Weaknesses, Opportunities, Threats) lens to evaluate the readiness of Rivers State's institutional and infrastructural environment for decentralized ontology adoption.

Results

Limitations of Centralized Ontology Development

The review confirmed consistent evidence of structural limitations in centralized ontology engineering. Centralized models, while ensuring semantic consistency and authority validation, systematically constrain scalability, restrict collaborative participation, and impede timely adaptation to evolving domain knowledge. Governance challenges, including authority bias and cross-institutional consensus failures, were identified as recurring impediments, particularly in multidisciplinary settings (Yang et al., 2019; Zhang et al., 2022). These findings confirm that centralized paradigms are increasingly misaligned with the dynamic, collaborative demands of contemporary knowledge systems.

In the Rivers State context, this misalignment manifests concretely: the state's four oil-producing local government areas (Khana, Tai, Gokana, and Eleme) generate substantial petroleum sector data that is managed by separate corporate and governmental systems with no semantic interoperability. Similarly, the agricultural knowledge base cultivated by the Rivers State ADP across twenty-three local government areas exists in disaggregated spreadsheets and paper records, rendering it inaccessible for cross-domain policy analysis.

Decentralized Technologies for Ontology Engineering

Three primary enabling technologies were identified as central to decentralized ontology development. First, blockchain technology provides immutability, provenance tracking, and distributed consensus mechanisms that reinforce trust and accountability in collaborative ontology construction (Zhang et al., 2022; Hasnain et al., 2017). Permissioned blockchain architectures, such as Hyperledger Fabric, are particularly suited to institutional environments where identity management is required, making them applicable to Rivers State government agencies. Second, the InterPlanetary File System (IPFS) enables content-addressed, decentralized storage, ensuring persistent and tamper-resistant ontology versions without reliance on central servers, a critical advantage given the intermittent power supply and connectivity challenges faced by institutions in Rivers State. Third, distributed ledger technologies support transparent, auditable records of ontological changes, facilitating governance across autonomous contributors.

These technologies, when integrated with semantic web standards (RDF, OWL 2, SPARQL), offer a robust infrastructure for decentralized ontology systems. The combined use of blockchain for governance and IPFS for storage represents the most technically mature integration pathway identified in the reviewed literature, and is directly applicable to the Rivers State e-governance infrastructure currently being developed under the Rivers State Government's Digital Economy Initiative.

Existing Decentralized Frameworks and Their Evaluation

Several frameworks for decentralized ontology engineering were identified and evaluated. The NeON framework promotes modular, reusable ontology networks, supporting community-driven evolution and contextual adaptation (Keet, 2021). Zhang et al. (2022) proposed a blockchain-integrated framework incorporating distributed consensus and provenance tracking, demonstrating enhanced trust and accountability. Konys and Drążek (2020) advanced community-curated, reusable domain ontologies within decentralized platforms, prioritizing inclusivity and adaptability. However, all identified frameworks exhibited limitations in semantic alignment across independently constructed modules, consistency maintenance without centralized oversight, and tooling support for distributed collaboration (Gruber, 1995; Chatterjee et al., 2021). None of the reviewed frameworks had been empirically validated in a sub-Saharan African context, representing a critical gap that the current study seeks to address.

Ontology Features and Functional Characteristics

The review identified three core functional features that distinguish ontologies from traditional classification systems: (i) domain terminology, enabling fine-grained technical distinction relevant to expert users; (ii) lay terminology, facilitating non-expert interaction and broader stakeholder engagement; and (iii) automatic inference, supporting computer-assisted knowledge alignment and extension across domains (Chatterjee et al., 2021; Qi et al., 2020). These features underscore the superiority of ontological representations over conventional taxonomies, particularly in

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dynamic, multi-domain environments such as Rivers State, where semantic interoperability across health, agriculture, education, and petroleum sectors is essential for effective governance and development planning.

Rivers State Knowledge Landscape: Applications and Infrastructure Gaps

Ontology-relevant applications in Rivers State span five domains: (i) petroleum and energy (oil field data management, environmental monitoring); (ii) health (RSUTH clinical records, primary health care data, maternal health tracking); (iii) agriculture (ADP extension records, mangrove ecosystem knowledge, aquaculture data); (iv) language and culture (Ijaw, Ikwerre, Kalabari, Ogoni, and over forty other ethnolinguistic groups); and (v) education and governance (FCE(T) Omoku course ontology, Rivers State Ministry of Finance data systems). These domains collectively affirm the practical relevance of ontological systems in Rivers State's digital transformation agenda.

However, a contextual SWOT analysis reveals significant readiness gaps. Strengths include an established tertiary education sector (Rivers State University, University of Port Harcourt, FCE(T) Omoku), growing ICT adoption, and a policy environment supportive of digital transformation. Weaknesses include inadequate ontology tooling expertise, insufficient infrastructure for decentralized storage, and weak inter-institutional data sharing frameworks. Opportunities include the Rivers State Government's digital economy initiative, international development partnerships, and the growing indigenous computing community. Threats include cybersecurity risks, governance instability, and potential stakeholder resistance to shared knowledge governance. These findings establish a compelling need for the proposed conceptual framework.

Discussion

The Paradigm Shift: From Centralized to Decentralized Ontology Engineering

The findings of this review collectively substantiate a paradigmatic shift in ontology engineering from centralized, expert-governed models toward open, participatory, and community-driven frameworks. This transition is not merely technological but epistemological and it conceptualizes ontologies as evolving communal assets rather than static authoritative structures. Decentralized approaches align more effectively with the distributed, multi-stakeholder nature of contemporary knowledge systems, enabling real-time collaboration, transparent governance, and contextual adaptability that centralized models cannot readily provide. This shift has profound implications for Rivers State, where the diversity and geographic distribution of domain expertise across twenty-three local government areas render centralized curation both impractical and inequitable.

Comparative Strengths and Persisting Challenges

While decentralized frameworks offer clear advantages in scalability, transparency, and community engagement, significant challenges remain. Semantic consistency across independently developed ontological modules presents a critical technical challenge, as divergent conceptualizations may undermine interoperability. Version control in distributed environments, without a central arbiter, remains methodologically unresolved. Furthermore, the predominance of tooling designed for centralized workflows, notably Protégé and OntoEdit, limits the practical implementation of decentralized models. Governance frameworks capable of adjudicating disputes, ensuring quality, and maintaining ontological coherence across autonomous contributors are notably absent from the existing literature. These challenges are compounded in Rivers State by limited technical capacity among potential ontology contributors and the absence of a coordinating body for knowledge management standards.

Implications for Rivers State and Developing Regions

The Rivers State context presents a compelling and nuanced case for decentralized ontology adoption. The richness and diversity of indigenous knowledge domains, spanning traditional medicine practices documented across Ijaw communities, mangrove ecosystem management knowledge held by fishing communities in Bonny and Brass, and agricultural practices developed by Ogoni farmers over generations, are ill-served by centralized frameworks that concentrate curatorial authority and limit contributor diversity. Decentralized ontology systems offer the potential to democratize knowledge representation, enabling distributed expert communities across institutions and geographic regions to contribute collaboratively.

The economic implications are also significant. The Rivers State Government's annual budget allocation to health and agriculture exceeds ₦180 billion (Rivers State Government, 2023). Improved semantic interoperability across these sectors, enabled by decentralized ontologies, could reduce data reconciliation costs, improve service delivery

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targeting, and enhance evidence-based policy formulation. Realizing this potential requires targeted investment in infrastructure, capacity building, and the development of governance models tailored to the local socio-technical context.

A Proposed Four-Layer Conceptual Framework

Based on the synthesized evidence and the specific contextual requirements of Rivers State, this study proposes a four-layer conceptual framework for decentralized ontology development (Table 2). Layer 1 (Infrastructure) employs blockchain and IPFS for secure, immutable, distributed ontology storage and version management, addressing the power and connectivity constraints of Rivers State institutions through IPFS's offline-first architecture. Layer 2 (Governance) establishes community-driven validation protocols with distributed consensus mechanisms modelled on open-source software governance, with adaptations for the multi-ethnic, multi-institutional landscape of Rivers State. Layer 3 (Semantic Engineering) mandates the adoption of OWL 2 and SPARQL for ontology specification and querying, with modular design principles facilitating domain-specific extensions across the state's priority sectors. Layer 4 (Application Interface) provides domain-specific ontology editors and reasoners adapted for distributed collaboration, including user-friendly interfaces designed for non-expert contributors such as agricultural extension officers and community health workers.

Table 2: Proposed Four-Layer Conceptual Framework for Decentralized Ontology Development

Layer	Component	Technologies/Mechanisms	Rivers State Application
Layer 1 – Infrastructure	Distributed storage & version control	Blockchain (Ethereum/Hyperledger), IPFS	Oil sector data, RSMOHSS health records
Layer 2 – Governance	Community validation protocols	Distributed consensus (DAO models)	Multi-institutional RS governance bodies
Layer 3 – Semantic Engineering	Ontology specification & querying	OWL 2, SPARQL, RDF, modular design	Creole/Kalabari language, RS agri domains
Layer 4 – Application Interface	User-friendly distributed editors	Adapted Protégé, WebProtégé, API gateways	RSUTH clinical staff, RS extension officers

Source: Authors' conceptual synthesis (2024); RS = Rivers State; RSMOHSS = Rivers State Ministry of Health and Social Services

This framework is intentionally modular, enabling phased implementation. A pilot programme is recommended for the FCE(T) Omoku education ontology developed by Egba (2022), which provides an existing foundational resource upon which the decentralized architecture can be built, validated, and subsequently extended to health and agriculture domains within Rivers State.

Conclusion

This study has demonstrated that centralized ontology development frameworks, while foundational to the field, are structurally inadequate for the dynamic, distributed, and collaborative demands of contemporary knowledge engineering. Decentralized approaches, enabled by blockchain, IPFS, and distributed ledger technologies, offer a credible and theoretically robust alternative, with demonstrated advantages in transparency, scalability, and participatory governance. The Rivers State context presents an especially compelling case for decentralized ontology adoption, given the richness and geographic distribution of its domain knowledge across petroleum, health, agriculture, language, and governance sectors. The proposed four-layer framework provides a conceptual foundation for future implementation and empirical investigation, grounded in the specific socio-technical realities of Rivers State and applicable to comparable developing-country contexts across sub-Saharan Africa.

Recommendations

Based on the findings and proposed framework, the following recommendations are advanced:

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1. Future research should undertake empirical validation of the proposed four-layer framework through pilot deployments targeting the Rivers State agricultural, health, and education sectors, commencing with the existing FCE(T) Omoku education ontology as a proof-of-concept environment.
2. The Rivers State Government should establish a State Ontology Governance Board comprising representatives from the Rivers State University, RSUTH, the ADP, and civil society organizations, with a mandate to develop and enforce decentralized ontology standards aligned with national e-governance objectives.
3. Ontology tool developers and the international semantic web community should prioritize the adaptation of existing editors, particularly WebProtégé, to support distributed collaboration workflows compatible with IPFS-based storage and low-bandwidth environments characteristic of rural Rivers State.
4. National bodies, including the National Information Technology Development Agency (NITDA) and the Rivers State ICT Agency, should develop governance standards for decentralized ontology systems that reflect local socio-technical realities and provide a regulatory framework for community-governed knowledge assets.
5. Interdisciplinary partnerships between computer scientists, domain experts (petroleum engineers, agronomists, clinicians, linguists), policymakers, and community stakeholders should be institutionalized within Rivers State universities to support sustainable, inclusive ontology development, with formal recognition in research evaluation frameworks.
6. Systematic quality assurance mechanisms, including automated OWL 2 consistency checking, SPARQL-based validation protocols, and peer validation workflows, should be integrated into decentralized ontology platforms deployed in Rivers State, ensuring semantic integrity without reliance on a central authority.

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