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Article

The Development of User-Centric Design Guidelines for Web3 Applications: An Empirical Study

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Abstract: The design of Web3 applications presents unique challenges due to their complex technical requirements. Despite the increasing spread of this technology, there is a notable lack of comprehensive, empirically grounded design guidelines for developing user-friendly Web3 interfaces. This study addresses this gap through a systematic three-phase approach: (1) developing initial guidelines from a literature review and industry sources (n = 31), (2) conducting evaluations using a 14-point framework based on the initial guidelines to test its effectiveness across diverse Web3 applications (n = 25), and (3) validating refined guidelines through expert evaluation sessions (n = 7). Expert evaluations highlighted the need for task-oriented rather than category-based organization of design principles. Based on these findings, we developed a structured framework organizing guidelines into four key task flows, each with three implementation levels. The framework emphasizes progressive disclosure of blockchain concepts, integrated user education, and clear state visualization. Our findings contribute to academic discussion and industry practice by providing empirically validated patterns for Web3 interface design. This study lays a foundation for creating more accessible and user-friendly decentralized applications, though future work should focus on longitudinal validation and adaptation to emerging technologies.

Keywords: Web3 design; user experience; blockchain; design guidelines; decentralized applications; interface design; Web3

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1. Introduction

If in 2004 we saw how the World Wide Web changed from Web 1.0 to Web 2.0 and let users create and share content online [1], today we see it changing in a new way, moving towards Web3.

Web3 uses blockchain technology, providing decentralized app architecture [2–4]. Web3 is not just cryptocurrencies; it gives an overall shift towards user ownership online [5] that creates a new online world.

Web3 creates new opportunities for user empowerment and data ownership and gives people greater control over their digital identities and online interactions, encouraging a more decentralized internet experience. It offers better security and transparency than Web 2.0 [2,3,6]. Web3 introduces new challenges for user experience (UX) design because customary design frameworks battle to change the one-of-a-kind characteristics of blockchain-based applications—designers must find new ways to meet these challenges.

Users must understand and apply complicated technical and financial concepts such as cryptocurrency wallets, gas fees, and smart contracts. The technical aspects of decentralized systems often create significant barriers to user adoption and usability issues [4,7,8].

Despite the growing awareness of UX challenges in Web3, there is a notable lack of extensive design guidelines. Existing research has primarily focused on the technical and developmental aspects of Web3. Academic research and industry-related sources offer limited publications on UX design in Web3. This gap leaves designers without clear guidance on how to create user-centric Web3 applications.

This study emerged from a broader PhD research program titled User-Centric Design for Health Wearables: Exploring Blockchain Adoption for Data Privacy and Control. While the doctoral research investigated the development, design, and ethical issues of health wearables and blockchain technology adoption, this completed study focused specifically on Web3 design guidelines, addressing the following research questions (RQs):

- What are the usability challenges specific to Web3 applications? (RQ1)
- How do current Web3 applications address these challenges? (RQ2)
- What design principles can be defined to guide the development of Web3 applications? (RQ3)

To address these research questions, we developed and validated design guidelines through a systematic three-phase methodology. First, we synthesized preliminary guidelines by analyzing 31 sources, including academic research and industry perspectives. This comprehensive review established a theoretical foundation while capturing current best practices from the field.

To evaluate and refine these initial guidelines, we took an innovative approach: we adapted the heuristic evaluation methodology to assess how well our guidelines served as evaluation criteria. We systematically examined 25 diverse Web3 applications—from cryptocurrency wallets and DeFi protocols to NFT marketplaces and social platforms. We evaluated each application against 14 specific heuristics derived from our guidelines, allowing us to identify effective design patterns and areas where our framework needed enhancement. This approach helped us understand how effectively our guidelines captured and guided these solutions.

Finally, we validated the refined guidelines through structured evaluation sessions with seven Web3 and UX design experts, who applied them to concrete design tasks. Their practical application and feedback helped ensure the guidelines were theoretically sound and valuable for real-world design challenges.

The primary aim of the study is to gather and verify the design techniques while working on blockchain-based products, systemize them, and provide additional suggestions. It will also generate the design requirements to help increase the user's understanding of data and manipulations performed with it.

This research contributes to human–computer interaction studies about Web3 applications by offering empirically grounded design guidelines. These guidelines can potentially improve the usability of Web3 applications, increasing the spread of the technology overall. We hope to lay a solid groundwork for future research in this evolving field by thoroughly documenting our methodology and findings.

This paper is organized as follows: Section 2 reviews related work in Web3 technologies, user experience challenges, and current design approaches and identifies gaps in existing research. Section 3 details our three-phase methodology, including developing draft guidelines, heuristic evaluation of Web3 applications, and expert validation process. Section 4 presents our findings, including the heuristic evaluation results, framework refinement, and expert evaluation outcomes. Section 5 discusses our findings and the study's limitations while suggesting future research directions. Section 6 concludes the research with a summary of contributions.

2. Related Work

Web3 symbolizes a shift of the paradigm towards a decentralized internet. It extends the technical standards of the Web [9]. To understand the unique design challenges posed by Web3 applications, it is crucial first to describe the fundamental concepts and technologies underlying this new paradigm.

The concept of Web3 is a response to the increasing centralization and data ownership monopolization observed in Web2. If we look at the evolution of the Web, Web1 provided static, read-only content, Web2 introduced interactive and user-generated content, and now Web3 promises a decentralized, user-centric Internet [1,10,11].

2.1. Blockchain Technology

At the core of Web3 lies blockchain technology, first introduced by Nakamoto [12] as the primary mechanism for Bitcoin. Blockchain is a distributed ledger technology that enables a tamper-resistant, shared record of transactions across a network of computers [12].

Building upon this foundation, Buterin [13] introduced the concept of smart contracts in Ethereum, allowing for self-executing scripts on top of the blockchain infrastructure [14]. These smart contracts are not limited to financial transactions; they can handle various applications, providing developers with opportunities to build decentralized applications (DApps) [15]. Smart contracts are essentially scripts that run on the Ethereum blockchain within a Turing-complete environment known as the Ethereum Virtual Machine (EVM) [16,17].

Smart contracts enable several key operations on the blockchain. They can write data by modifying variable states, retrieve existing data from the blockchain's current state, and perform various computations and operations with these data.

All operations that change the state of the blockchain, including data mutations, are called transactions. To perform these transactions, users must pay a fee known as "gas" [18]. This gas fee compensates for the computational resources required to process and validate the transaction on the blockchain network.

Smart contracts have significant implications for UX design in Web3 applications. Smart contracts execute complex operations automatically, reducing the need for user intervention and potentially obscuring processes from the user's view [19]. Smart contracts cannot be modified once deployed, emphasizing the need for careful design and user education before interaction [20]. Users must learn to interact with DApps using transactions, a concept new to most Web2 users [21].

2.2. User Experience Challenges in Web3

The uniqueness of blockchain technology and the overall Web3 ecosystem introduces new challenges for user experience design. They can vary from the complexity of blockchain interactions to the need for new mental models and heightened security considerations.

One of the most significant barriers to the mass adoption of Web3 is the complexity of interacting with blockchain systems [22]. Users face challenges managing private keys and wallets, which are fundamental to participating in Web3 ecosystems [23,24]. The responsibility of safeguarding these cryptographic keys and the irreversibility of blockchain transactions creates a high-stakes environment that can discourage users [25,26].

The work of Ray [8] partially discusses the UX in Web3. According to Ray [8], key issues include potential misuse of data and identity, the need for robust governance and security frameworks, data interoperability, and user-friendly privacy technologies. They also suggest that Web3 must promote education on these topics and engage users transparently.

The concept of paying variable fees for computational resources alienates most Web2 users and can lead to confusion and frustration. Designers must explain these complex mechanisms in user-friendly terms and provide interfaces that help users make informed decisions about their actions [22]. Prioritizing user experience in Web3 has the potential to overcome adoption barriers and improve user engagement within the decentralized ecosystem [8].

Web3 requires users to adopt new vocabulary and mental models. There are common misconceptions about blockchain technology among users, and many struggle to understand concepts like gas fees, decentralization, and hash functions.

2.3. Security and Privacy Concerns

User perception of security in Web3 remains a critical factor influencing its adoption and trust. The study by Shin and Hwang [27] found that users' trust and satisfaction with blockchain technologies are significantly influenced by their appreciation for its transparency and reliability. User attitudes towards blockchain are influenced by cognitive heuristics, which shape how they perceive and interpret the technological features of the system [27].

Security and privacy are primary factors influencing trust and behavioral intent in blockchain users. Users' cognitive processes embed these aspects into their trust in the technology [28].

Transparency is a core idea of many blockchain-based systems. Balancing it with privacy needs is a significant challenge. While blockchain's immutable record provides transparency, it raises concerns about long-term privacy implications [29].

2.4. Emerging Trends in Web3 UX Design

As Web3 technologies continue to be developed, new trends that might have implications for UX design appear. Most developments aim to address scalability issues, enhance interoperability, or leverage artificial intelligence.

2.4.1. Layer 2 Solutions and UX Implications

Layer 2 blockchain protocols improve transaction processing rates, times, and fees by minimizing reliance on the underlying slow and costly blockchain. These protocols can transform the blockchain domain using the main chain primarily for trust establishment and dispute resolution [30]. Still, it places a risk of users being unaware of precise manipulations with their data.

Users face difficulties securely and quickly transferring funds between the main-chain and Layer 2 systems and between different Layer 2 projects [31]. This complexity can obstruct the overall user experience and scalability potential of Layer 2 solutions.

Moreover, Neiheiser et al. [31] found that current Layer 2 systems in Ethereum have limited scalability potential due to technical aspects and user behavior, and approaches that sacrifice security for higher throughput may increase centralization.

2.4.2. Cross-Chain Interoperability

As the blockchain ecosystem becomes increasingly diverse, some users experience challenges in multi-chain environments. Achieving efficient and scalable cross-chain interactions is challenging. Users often experience delays and high costs associated with cross-chain transactions, which can negatively influence the overall user experience, with an additional need for user education on security [32,33].

Cross-chain solutions are often centralized and require significant re-engineering of the core blockchain stack, making them complex and less user-friendly. Madine et al. [34] proposed the appXchain that addresses this issue using DApps as a distributed translation layer.

2.4.3. Integration of AI in Web3

Integrating AI with blockchain raises significant cybersecurity and data privacy issues, particularly in decentralizing machine learning processes among peer-to-peer networks [35]. Blockchain functionalities encounter difficulties in accommodating evolving service demands and achieving scalability [36].

Guergov and Radwan [37] raise important considerations: ensuring trust and accountability in communications and transactions is a significant challenge when integrating AI with blockchain, especially in IoT environments. Their study suggests that successful integration will help create new business models and support the digital transformation of companies.

Ray [8] suggests that AI and ML can make DApps better at predicting market trends, spotting fraud, and suggesting personalized content to users. By using AI and ML, Web3 projects can become faster, safer, and able to handle more users and data.

2.5. Ethical Considerations

Web3 technologies aim to reshape digital interactions, and it is necessary to consider the ethical implications and ensure they are designed with inclusivity and user empowerment in mind.

Cong et al.'s [38] research indicates a significant concentration of cryptocurrency wealth and mining rewards among a limited number of participants in the blockchain ecosystem. This concentration persists even when excluding major institutional actors such as exchanges and mining pools, suggesting that the distribution of resources in these digital economies may exhibit greater inequality than in traditional economic systems.

Their study further indicates that specific mechanisms, such as base-fee burning protocols and token distribution initiatives (airdrops), potentially contribute to inclusivity and economic parity by redistributing digital assets within the ecosystem [38].

2.6. Gaps in Current Research

Despite the growing popularity of Web3 and several publications mentioning its UX, significant gaps remain in our understanding and approach to designing for the new type of ecosystems.

The existing research on Web3 UX is often fragmented or focused on specific aspects of blockchain interaction. There is a notable absence of comprehensive, empirically grounded design guidelines that address the full spectrum of Web3 user experiences.

This gap shows the need for comprehensive design principles to help create user-friendly Web3 applications for different use cases.

Furthermore, most Web3 applications are very recent. This results in a lack of longitudinal studies examining user adoption and interaction patterns over extended periods. These studies are necessary to understand the long-term influence of various design decisions and develop user-centric ecosystems. The lack of validated design guidelines and limited real-world user studies present opportunities for further research.

2.7. Methodologies for Development of Design Guidelines

The systematic development of design guidelines represents a crucial area in human–computer interaction (HCI) research, with various methodological approaches evolving over time. The process of creating effective design guidelines requires careful consideration of data collection, validation, and refinement methods to ensure their practical utility and theoretical soundness.

Design guidelines in HCI are commonly derived through a multi-phase, iterative process that combines comprehensive literature reviews, empirical testing, and expert consultation. As Ogunyemi et al. [39] highlight, creating guidelines for emerging technologies benefits from drawing upon both established usability principles and domain-specific insights. Similarly, Rosa and Silveira [40] emphasize the importance of iterative refinement and stakeholder engagement to ensure that guidelines address real-world problems effectively. These methods align with broader findings in HCI, which show the value of integrating systematic approaches to refine and validate guidelines [41].

In line with these methodological recommendations, our guideline development involved:

1. Synthesizing insights from both academic and industry-based sources
2. Converting these findings into heuristic criteria for structured evaluations of existing Web3 applications
3. Refining the guidelines through expert reviews and design tasks.

By aligning with recognized HCI best practices and incorporating domain-specific requirements, our process ensures that the resulting guidelines are empirically grounded and adaptable to Web3's distinct technical and user-experience contexts. This approach is consistent with Subramanian et al. [42], who highlight the necessity of methodical categorization and refinement to address domain-specific challenges, and Zaphiris and Kurniawan [43], who underscore the value of systematic validation in guideline development.

3. Materials and Methods

This chapter presents our three-phase methodology for developing and validating design guidelines for Web3 applications. First, we describe our systematic approach to synthesizing initial guidelines from industry sources, expert insights, and academic research. Then, we detail the heuristic evaluation process used to assess and refine these guidelines by analyzing 25 existing Web3 applications. Finally, we present our expert evaluation methodology, where the refined guidelines were validated through structured sessions with Web3 and UX professionals. Each phase builds upon the findings of the previous one, creating an iterative process of guideline development and validation.

3.1. Development of Draft Guidelines

We followed a systematic and thorough process to develop the initial draft of Web3 design guidelines, bridging insights from industry expertise and academic research. We began with identifying key sources of Web3 design knowledge. These sources included blog posts, articles, and other online materials authored by experts in Web3 UX design, as well as technical documentation from prominent Web3 platforms. We also consulted industry reports and summaries from consulting firms and research organizations. Recognizing the importance of grounding our work in academia, we sought out relevant papers from the fields of HCI and UX design that explored the Web3 space.

3.1.1. Quote Extraction and Initial Matrix

In total, we selected 31 sources to inform our analysis. The selection criteria prioritized relevance to Web3 user experience, interface design, and recency. For industry-based resources, we focused on content published within the last three years, while older works (dating back to 2017) were included if they were cited in more recent materials. In the case of academic papers, we extended our scope to include publications from the past five years. Despite the limited academic literature on Web3 design, we successfully identified and integrated 18 papers that addressed topics such as blockchain user experience, decentralized application design, and relevant HCI principles.

Each source was reviewed, with particular attention given to the design challenges they highlighted, the proposed solutions, the emerging trends they identified, and their advice for the development.

We began by systematically reviewing 31 sources, encompassing academic references and industry-related materials. For each source, we:

1. Extracted quotes directly mentioning or implying design-related challenges, solutions, or emerging patterns relevant to Web3 interfaces.
2. Compiled these quotes in a structured manner and **labeled** them with preliminary tags (e.g., "usability", "visual design", "emerging trends", "wallet integration").

To facilitate consistent analysis, we created a matrix for each source, listing the design issues and solutions in the **rows** and four broad themes—Usability, Visual Design, Emerging Trends, and Others—in the columns. This approach enabled a side-by-side view of problem statements and proposed remedies, making identifying overlap, recurring themes, and potential gaps easier.

Our analysis revealed significant patterns across sources. From academia, Lai et al. [44] identified that streamlined interfaces and workflows were necessary for ordinary users, while highlighting data ownership and user empowerment. Murray et al. [45] emphasized how users could revoke access to applications at any time through their wallets. Sadowski et al. [46] noted challenges with visibility of expansive communities in the Web3 ecosystem.

Interface and interaction challenges were prominent themes. The Coinbase design team [47] highlighted how the industry struggled to explain itself, noting there were "no easy analogs for crypto". Gan et al. [1] discussed the importance of standardized APIs, while Teruel and Trujillo [48] detailed how each blockchain requires unique wallet interaction mechanisms.

Trust and transparency emerged as critical considerations. Gabriele et al. [49] emphasized users' need for support when making key decisions about data sharing. Große et al. [50] identified trust-affecting uncertainties across transaction lifecycles. Froehlich et al. [51] documented frequent misconceptions about key management, transaction fees, and security aspects.

Community and governance aspects were highlighted by several researchers. Cila et al. [52] emphasized how communities need control over system rules and the ability to renegotiate them. Murray-Rust et al. [53] found that roleplay and collaboration were effective for understanding technical features. Pschetz et al. [54] stressed the importance of transparency in managing transactions.

Wallet design and security received significant attention. Yu et al. [55] found users preferred mobile wallets for convenience while identifying needs for improved security alerts and phishing protection. Chen and Ko [56,57] explored how AR features could enhance user engagement and trust in blockchain applications. Zeng et al. [58] noted how limited social presence affected transaction behaviors.

Educational and onboarding considerations were consistently emphasized. Froehlich et al. [59] outlined specific challenges for new cryptocurrency users. Kwon et al. [60] identified how usability problems increased participation costs. Glomann et al. [61] stressed the importance of precise onboarding dialogs.

Industry practitioners provided crucial insights into practical implementation. Ko [62] identified specific challenges such as unclear network selection. In the Web3 Design Principles [63] clarifying data sources and transaction irreversibility were stressed. The UX and Web3 Design Guide [64] highlighted the importance of seamless onboarding and importance of public product documentation.

User experience frameworks emerged from various sources. Oluwasegun [65] outlined key questions for Web3 design and development. Benji [66] established core principles of simplicity, fluidity, and delight enhanced with progressive animations. Crabb [67] provided focused 7 heuristics for Web3 interface design. The Consensys team [68] emphasized eliminating user friction in wallet interactions and importance of instant user onboarding.

Recent industry perspectives added valuable insights. Gnanam [69] stressed clear language, control over data and visual explanations. Mills [70] emphasized actionable data presentation and continuous feedback. The CRADL Report [71] highlighted the crucial distinction between early and majority adopters. Jason K. [72] emphasized progressive growth principles, while Beltran [73] provided detailed guidelines for building Web3 applications.

3.1.2. Thematic Categorization and Subgrouping

To synthesize, we employed a thematic analysis approach. Initially, we grouped the insights into 21 preliminary themes. Through iterative refinement, we coded and categorized the data, identifying recurring patterns and opinions while noting contradictions and inconsistencies. Subgroups were formed to address nuanced distinctions within broader themes, and we worked diligently to validate the relevance of each insight for the Web3 design community. The synthesis also involved integrating theoretical frameworks from academic research with practical knowledge from industry resources.

We transferred relevant quotes and insights from each source's matrix into a master matrix, generating an extensive list of preliminary design themes. We grouped these quotes into 21 initial categories, including, for example, "data control", "familiar interface", "trust", "wallets", "action irreversibility", "privacy", "smart contract design", "vocabulary", "communities", "complexity", "active support", and "education".

During subsequent rounds of analysis, categories with limited data or overlapping scopes were merged or reassigned. For instance, privacy was moved to the "Other" category and then re-sorted, while smart contract design was absorbed under "transparency," and key management was consolidated into the "wallet" category. This iterative refinement left us with a smaller, more coherent set of key themes aligned with user needs and technological characteristics of Web3.

3.1.3. Contradictions, Dominant Opinions, and Web3-Specific Choices

After establishing the categories, we systematically reviewed each to detect supporting versus contradictory points across sources. Where multiple sources converged on a specific recommendation—such as the importance of continuous user feedback or the need for integrated onboarding flows—those points were carried forward into the guidelines.

In some cases, the literature was equally divided, creating design tensions. A notable contradiction revolved around familiar account management (e.g., email plus password) versus purely wallet-based authentication. In scenarios of a tie, we favored the solution that most strongly harnessed the potential of Web3—i.e., wallet-based approaches—since they offer a key differentiator from Web2 solutions.

Additionally, contradictory preferences regarding friction and user education emerged: Some practitioners argued for frictionless user flows (e.g., hidden technical details), while others promoted explicit exposure of Web3 concepts to empower user understanding. Whenever evidence was balanced, we leaned toward recommendations emphasizing a clear, Web3-centric value proposition (such as letting users decide how much blockchain detail they want to see).

3.1.4. Summarizing Each Topic and Forming the Draft Guidelines

For each category that remained after pruning and subgrouping, we developed a summary of the main points, including the following:

- Key usability or user experience challenges (e.g., confusion around gas fees, irreversible transactions).
- Typical or recommended solution patterns (e.g., progressive disclosure, confirmations for high-stakes actions).
- Critical design implications (e.g., designing for trust, providing education via small "info bites").

Using these summaries, we clustered insights into more actionable guidelines. To make them easily navigable and scalable to different project phases, we designated three implementation levels—MVP (Minimum Viable Product), Standard Product, and Full Product—each building on the previous set. These levels reflect practical considerations such as project resources, user adoption stage, and product maturity.

The final stage of this process was formulating an initial set of Web3 design guidelines. Each guideline was carefully crafted to address specific challenges within the Web3 ecosystem. To ensure their utility, the guidelines were designed to be actionable, evidence-based, and broadly applicable across various Web3 domains. Wherever possible, they were supported by a convergence of insights from both industry and academic sources, providing a robust foundation for designers navigating the unique demands of Web3 development.

3.2. Preliminary Evaluation

To verify our initial design guidelines, we adapted the heuristic evaluation methodology, traditionally used for usability assessment, as a systematic framework for testing the guidelines. Unlike traditional heuristic evaluation that assesses application usability, our adapted approach used the draft guidelines as evaluation criteria to test their effectiveness and comprehensiveness.

3.2.1. Rationale for Using Adapted Heuristic Evaluation

We chose heuristic evaluation as a systematic method to test and validate our proposed guidelines. This approach offered a structured way to verify whether our guidelines effectively addressed real-world Web3 design challenges. By methodically applying these guidelines as evaluation criteria across diverse applications, we could assess:

- How well the guidelines translated into practical evaluation criteria
- Whether they comprehensively covered Web3-specific design considerations
- How effectively they could guide designers in creating or improving Web3 interfaces

Notably, while our process involved reviewing real-world interfaces, the purpose was not to evaluate these applications but to use them as test cases to determine if our guidelines were sufficiently robust and applicable.

3.2.2. Selection of Applications

The applications were selected based on several important factors. We prioritized popular platforms that had achieved significant user adoption. We also ensured representation across different Web3 sectors to capture diverse functionality. Additionally, we specifically chose applications that did not require substantial financial investment to interact with, ensuring our evaluation could be comprehensive without economic barriers. Based on these criteria, we selected the following 25 applications (Table 1) across diverse Web3 application types for evaluation.

For cross-platform applications, we evaluated all available platforms (web, mobile iOS, mobile Android) to ensure our guidelines addressed platform-specific challenges and maintained consistency across different interfaces.

Table 1. Selected Applications.

Application	Category	External Wallet Used	Year Launched
Aave [74]	DeFi	MetaMask [75]	2020
Brave [76]	Browser, Wallet	N/A	2016
Braavos [77]	Wallet	N/A	2022
CerebrumDAO [78]	DAO, DeSci	None	2023
ChainGPT [79]	Ecosystem	MetaMask [75]	2023
CitaDAO [80]	DeFi, DAO	MetaMask [75]	2022
CryptoKitties [81]	NFT Marketplace	MetaMask [75]	2017
DappBack [82]	X-to-Earxn App	MetaMask [75]	2022
Decentraland [83]	Metaverse, Game, NFT Marketplace, DAO	MetaMask [75]	2017
Exchange.Art [84]	DeFi	MetaMask [75]	2021
GMX [85]	DeFi	Ronin Wallet [86]	2021
HairDAO [87]	DAO	Ronin Wallet [86]	2021
Mavis Market [88]	NFT Marketplace	Ronin Wallet [86]	2023
MetaMask [75]	Wallet	N/A	2016
Mirror [89]	Social media	MetaMask [75]	2020
Orb [90]	Social media	None [1]	2022
OpenSea [91]	NFT Marketplace	MetaMask [75]	2017
Paragraph [92]	Social media	Ronin Wallet [86]	2022
Phaver [93]	Social media	None	2022
Pixels [94]	Game	Ronin Wallet [86]	2021
Ronin Wallet [86]	Wallet	N/A	2021
Snapshot [95]	Tool for DAOs	MetaMask [75]	2020
StarkDeFi [96]	DeFi	Braavos [77]	2023
Sweat Wallet [97]	X-to-Earn App, DeFi	N/A	2023
Uniswap [98]	DeFi	MetaMask [75], Ronin Wallet [86]	2022

[1] Initially we tried using Trust [99], but the connection was not established successfully, and we proceeded without any external wallet.

Although we documented any usability insights observed in these applications, our primary purpose was to see how well the guidelines performed across different contexts rather than to publish a comparative usability study of each application.

3.2.3. Development of Heuristics Based on Draft Guidelines

To facilitate systematic testing, we transformed our draft guidelines into observable evaluation criteria (Appendix A). This translation focused on creating clear markers that could be consistently identified across different applications while maintaining the guidelines' core principles. The markers needed to be observable through interface design elements, allowing for consistent evaluation. Furthermore, we ensured they would broadly apply across various Web3 applications, making them valuable for diverse implementation contexts.

This resulted in 14 heuristics grouped into six categories, each addressing distinct aspects of Web3 usability. From fostering user understanding to ensuring seamless wallet integration, the heuristics were tailored to meet the unique demands of blockchain-based applications. For instance, while "User Understanding" emphasized adaptability to varying expertise levels, "Feedback Systems" ensured that every interaction was transparent and predictable. The detailed evaluation template used in this study is provided in Appendix B.

3.2.4. Evaluators

Two researchers with expertise in both Web3 technologies and HCI independently examined each application through the lens of our guidelines, which presents both limitations and specific advantages that warrant discussion. While a larger number of evaluators during this preliminary phase could have potentially provided additional perspectives, several factors support the validity of this approach within the context of a multi-phase validation process.

The two-evaluator approach was an initial screening phase rather than the final validation. This preliminary evaluation was specifically designed to:

- Identify major usability issues in the guidelines
- Test the practical applicability of the evaluation criteria
- Generate initial insights for refinement
- Prepare for the subsequent expert validation phase

Several aspects of the study design helped mitigate the limitations of having only two initial evaluators:

1. A more extensive expert validation phase followed the initial evaluation
2. Findings from the two-evaluator phase were treated as preliminary insights rather than definitive conclusions
3. The high agreement between evaluators suggested strong reliability in the assessment process

Both evaluators possessed extensive knowledge across Web3 development and UX/UI design, with one having deeper expertise in interface design and user research methodologies while the other had additional depth in development practices. This combination ensured that evaluations benefited from strong technical understanding and user-centered design principles while maintaining consistent evaluation quality across all assessment areas. Future research would benefit from involving more evaluators in the preliminary phase to capture broader perspectives.

3.2.5. Testing Process

The examination followed a structured process that allowed us to document how well each guideline translated to real-world implementations:

Initial Assessment

1. Initial exploration (2–5 min to become familiar with the application)
2. Review of available documentation
3. Feature identification and mapping

Detailed Evaluation

1. Systematic heuristic assessment
2. Documentation of specific instances
3. Screenshot collection for evidence
4. Identification of recurring patterns

We noted whether each observation represented a minor variation from our guidelines or suggested a more fundamental gap in our framework. This helped distinguish between implementation-specific choices and potential shortcomings in the guidelines themselves.

To maintain consistency in our assessment, we developed a basic evaluation scale to note the degree to which implementations diverged from our guidelines:

- 0—Not a problem
- 1—Cosmetic problem only
- 2—Minor usability problem

- 3—Major usability problem
- 4—Extreme usability problem

Evaluators would first note whether the application's interface supported or deviated from the guideline for each criteria. They then gauged the impact of this deviation on a typical user's task flow. If the deviation introduced only slight visual clutter, it might be rated a 1 (cosmetic) or 2 (minor). If it posed a risk of user error or confusion that stops tasks, they assigned a 3 (major) or 4 (extreme). After both evaluators completed their assessments, they discussed differences and settled on a consensus rating.

Data Collection Protocol

For each application, we documented:

1. Basic application context and intended use case
2. Notable implementation patterns
3. Supporting evidence (screenshots, interaction flows)
4. Examples of both aligned and divergent approaches
5. Unique or innovative solutions

Consensus Building

Following individual evaluations, researchers systematically compared their independent assessments, revealing a notably high level of agreement in their evaluations. The initial comparison of assigned scores across all heuristics demonstrated strong inter-rater reliability, with most variations being minor and easily reconcilable.

The evaluation process benefited from the researchers' shared expertise in Web3 technologies and HCI, resulting in consistently aligned assessments. When slight variations in scoring occurred, they typically differed by no more than one point on the severity scale. In these cases, researchers calculated the average of their scores, rounding to the nearest 0.5 to maintain precision while avoiding false accuracy. This straightforward averaging approach proved sufficient for all observed variations, as no significant discrepancies emerged during the evaluation process.

Following the scoring phase, researchers systematically synthesized their observations and insights. They thoroughly reviewed their individual notes, combining their findings into a comprehensive list of observed issues and potential improvements to the initial guidelines.

3.2.6. Analysis Framework

Our analysis focused on understanding how our draft guidelines manifested across different applications and contexts. We structured our examination across three complementary phases, each building upon insights from the previous one.

The first phase focused on identifying recurring implementation patterns. We looked for consistent themes in how applications interpreted and implemented concepts from our guidelines. This helped us understand which aspects of our guidelines were clear and actionable and which needed refinement. We paid particular attention to patterns within application categories, noting how different types of applications (wallets, marketplaces, DeFi platforms) approached similar challenges. We also observed how implementation patterns evolved between older and newer applications, providing insights into emerging best practices.

The second phase emphasized qualitative analysis of these patterns. We carefully reviewed our documented observations, screenshots, and notes to understand why specific patterns emerged and how they related to our guidelines. This revealed common approaches and innovative solutions that could inform guideline refinement. We focused especially on how applications handled core Web3 challenges like wallet integration and transaction signing, as these represented key test cases for our guidelines.

In the final phase, we assessed the comprehensiveness of our guidelines based on observed patterns. We identified gaps where applications demonstrated important usability considerations not covered by our guidelines. We also noted overlapping or redundant aspects of our guidelines that could be streamlined. This phase helped us understand where our guidelines needed expansion, consolidation, or clarification.

This systematic examination of real-world implementations helped us refine our guidelines to serve better needs in practical design while maintaining comprehensive coverage of Web3-specific considerations. The insights gained directly informed subsequent revisions to make the guidelines more actionable and relevant.

3.3. Guideline Refinement Process

Following our heuristic evaluation and analysis, we systematically refined the original guidelines based on our findings through a comprehensive study, including gap identification and validation.

3.3.1. Gap Identification

We began by analyzing the evaluation data to identify areas where the original guidelines failed to address observed usability challenges adequately. This involved examining:

- Cases where evaluators struggled to map observed issues to existing guidelines
- Scenarios where multiple sections overlapped in evaluating the same issue
- Instances where guidelines did not apply to certain application types
- Situations where technical aspects were not sufficiently covered

3.3.2. Refinement

Building on the identified gaps, we implemented a three-stage refinement process. The first stage focused on category organization, where we evaluated the relevance and completeness of existing categories, identified and addressed overlapping areas, assessed relationships between categories, examined progression logic, and consolidated redundant guidelines. In the second stage, we addressed level progression by analyzing the effectiveness of our three-level structure, identifying key transition points between levels, examining feature dependencies, and evaluating implementation complexity. The final stage involved cross-reference validation, where we meticulously checked coverage against identified issues, verified applicability across different application types, and confirmed comprehensive technical requirement coverage.

Throughout this refinement process, we maintained unwavering focus on several key objectives. We prioritized creating guidelines that would be practical to implement and clear to evaluate. The guidelines are needed to maintain flexibility for different application types while remaining scalable for future development. Additionally, we ensured all aspects were measurable for assessment purposes, allowing for consistent evaluation across implementations.

We refined our process and created guidelines that balance theory and practice. We guaranteed thorough coverage of many Web3-specific usability challenges by actively moving from gap identification, through structural analysis and content development, to validation while maintaining clear and consistent evaluation criteria. This framework evaluates usability consistently across multiple applications by embracing current Web3 patterns and new technologies.

3.4. Expert Evaluation

Following the preliminary evaluation using Web3 applications and subsequent refinement of our initial guidelines, we conducted expert user testing sessions to validate and improve the design guidelines. This section details our methodology for these evaluation sessions.

3.4.1. Participants and Recruitment

We recruited seven experts in UX design, Web3 design, and development. This number was chosen based on Nielsen and Landauer's [100] research showing that 5–8 expert evaluators can identify approximately 80–85% of usability problems, with diminishing returns beyond this range. Participants were required to have at least three years of professional or research experience in information technology and either be active users of Web3 applications or be involved in their development. The array of experts included UX designers, blockchain researchers, and developers.

3.4.2. Session Structure

Each expert testing session followed a structured format lasting approximately 50–70 min, divided into several phases:

1. Initial Setup (7–8 min)
    - Collection of informed consent
    - Welcome and session introduction
    - Explanation of the research background
2. Guidelines Introduction (4–6 min)
    - Overview of the refined guidelines
    - Explanation of the testing structure
    - Clarification of expected outcomes
3. Main Testing Phase (35–50 min):
    - Experts were asked to review and take notes on the design strategies presented
    - Then, apply the guidelines to a design task
    - As the final step to create a sketch for a Web3 interface
4. The testing session was followed by a semi-structured interview focusing on (10–15 min):
    - Overall impressions of the guidelines
    - Specific feedback on guideline contents
    - Process evaluation
    - Improvement suggestions
    - Implementation considerations

3.4.3. Design Task

Experts were presented with a real-world design scenario to evaluate the practical applicability of the guidelines.

Design Scenario: Web3 Wallet for Peer-to-Peer Transfers Participants were tasked with designing a Web3 wallet interface to enable beginners to transfer cryptocurrency to friends. The design needed a smooth, engaging, educational experience while addressing common user concerns about security, trust, and usability.

Task Context:

- Target users: Beginners in Web3/cryptocurrency
- Primary use case: Peer-to-peer money transfer

- Key challenges: First-time wallet use and crypto transfer

  Required Deliverables:

1. Screen 1: Onboarding Interface
   - Introduction to wallet functionality
   - Presentation of basic features
   - Initial user guidance
2. Screen 2: Transaction Confirmation
   - Clear transaction details
   - Trust-building elements
   - User-friendly confirmation process

For both cases, we suggested that participants deliver wireframes and not the final mockups due to the limited time during sessions. At the same time, they were also welcomed to work on the deliverables additionally after the session and share their outcomes with us.

The task was chosen explicitly as follows:

- Represents a fundamental Web3 interaction
- It encompasses multiple guideline categories
- Addresses critical user concerns
- Tests guideline applicability in a concrete scenario

To simplify the design workflow, the participants were provided with a template Figma file, where they could find two frames for the mobile app, a set of user interface components (based on Paper Wireframe Kit [101]), a design scenario and task, and our design guidelines.

3.4.4. Testing Protocol

The testing phase employed a combination of think-aloud protocol and task-based evaluation. Experts were asked to verbalize their thoughts while applying the guidelines to a design task. The task involved creating a sketch for a Web3 application, incorporating the provided design guidelines.

We structured the evaluation around three key aspects:

1. Guideline comprehension and clarity
2. Practical applicability in the design process
3. Potential impact on user adoption and acceptance

3.4.5. Data Collection

Our data collection methodology encompassed a comprehensive range of sources to ensure thorough documentation of the expert evaluation process. We recorded each session through both audio and video, capturing the full context of participant interactions and verbal feedback. Researchers maintained detailed written notes throughout the sessions to document observations and key insights. The experts provided their input through semi-structured interviews, and their design work was preserved through their produced sketches. These multiple data collection channels allowed us to capture explicit feedback and subtle nuances in how experts interpreted and applied the guidelines.

We developed a comprehensive framework for the semi-structured interviews to explore multiple aspects of the guidelines' effectiveness. Our questions examined participants' overall impressions and detailed evaluation of the guidelines' contents. We sought feedback on the process itself and gathered specific suggestions for improvements. The framework also explored practical implementation considerations, encouraging participants to reflect on both the strengths and potential weaknesses of the proposed guidelines.

3.4.6. Analysis Approach

Our analysis employed a thematic approach to synthesize insights from the collected data. We examined how experts applied the guidelines in practice, paying particular attention to common patterns that emerged across different sessions. The analysis delved into how well participants comprehended and utilized the guidelines while evaluating their design processes and methodologies. We carefully documented the challenges and limitations that experts encountered, along with their thematic feedback on the guidelines' effectiveness. The analysis paid special attention to implementation considerations and examined areas of consensus and disagreement among experts, providing valuable insights into the guidelines' practical applicability and potential areas for improvement.

4. Results

4.1. Initial Guidelines Framework

The first draft of guidelines was organized into a structured framework with three progressive levels of implementation: MVP (Minimum Viable Product), Standard Product, and Full Product. Each level builds upon the previous one, providing a clear path for incremental improvement in Web3 applications.

Level 1 (MVP) establishes nine fundamental categories essential for any Web3 application:

1. Core User Experience.
2. Essential Interface Design.
3. Onboarding and Navigation.
4. Wallet Integration.
5. Transaction Management.
6. Trust and Transparency.
7. User Control.
8. Community Features.
9. Value and Innovation.

Each category contains actionable guidelines focused on essential features. Subsequent levels (Standard Product and Full Product) build upon these foundations, adding more features and capabilities. This layered approach offers a scalable development framework. The complete set of initial guidelines is presented in Appendix A.

4.2. Preliminary Validation Findings

Our systematic testing of the guidelines using 25 Web3 applications revealed valuable insights about the guidelines' effectiveness and completeness. While we used a scoring system similar to traditional heuristic evaluation, these scores should be interpreted primarily as indicators of how well our guidelines detected different design decisions rather than usability ratings of the applications. The findings span three key areas: the guidelines' ability to identify relevant design patterns, their comprehensiveness across different application types, and areas where the guidelines needed refinement.

4.2.1. Overview

Using the heuristic scoring described in Section 3.2, we compiled an aggregated view of how frequently the guidelines detected usability friction. Figure 1 shows each application's overall severity score, derived by averaging all heuristic ratings. While some variation in "usability maturity" was apparent across applications, these scores are best interpreted as an indirect indicator of how thoroughly the guidelines could spot potential issues rather than a definitive measure of each app's quality.

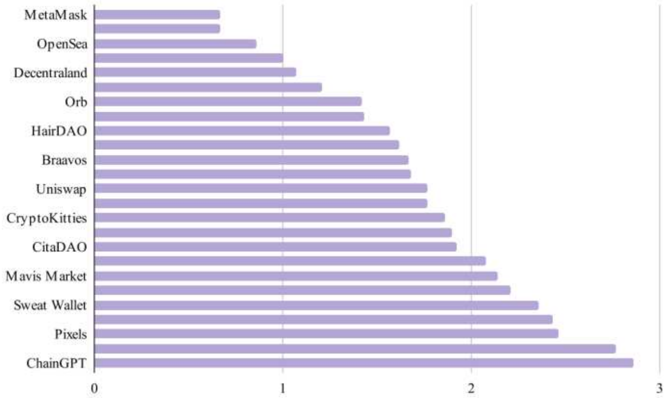

Figure 1. Severity scores per application.

Overall severity ratings averaged 1.736 (SD = 0.607), indicating that our guidelines successfully detected varying levels of alignment with Web3 design best practices. This distribution helped us identify which aspects of our guidelines most effectively captured important design considerations (Figure 2). Still, severe problems (scores above 3) were relatively uncommon. This distribution helped us see which heuristic categories—and thus which parts of the guidelines—were triggered often, signaling they might be particularly effective at identifying design pitfalls.

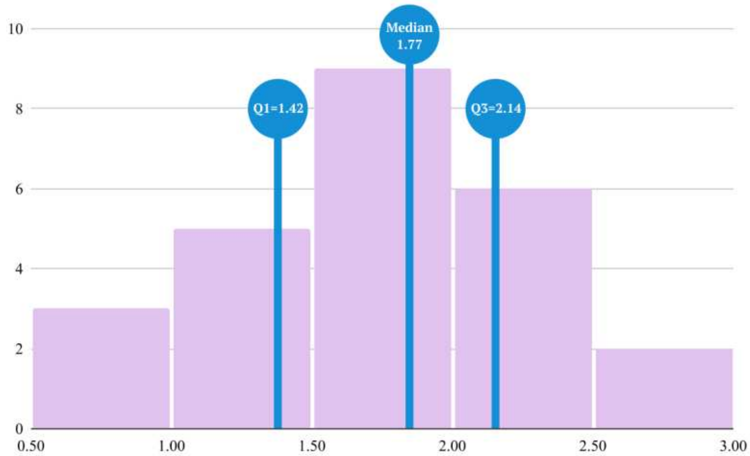

Figure 2. Distribution of severity scores.

4.2.2. Patterns by Application Category

To explore possible patterns in guideline applicability, we grouped the 25 applications according to general categories: DAO, DeFi, Wallets, Games, NFT Marketplaces, Social Media, and Others (combination of X-to-Earn apps, ecosystem, and DAO tool). Figure 3 shows the mean severity score per category, again reflecting how often the guidelines flagged usability concerns. Wallets and NFT marketplaces triggered relatively fewer usability violations on average (scores of 1.15 and 1.62, respectively), whereas Ecosystem and certain X-to-Earn apps highlighted more design challenges (mean scores around 2.1).

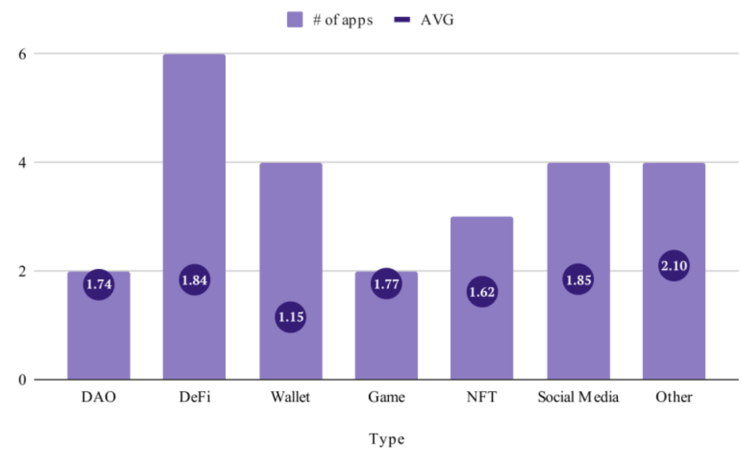

Figure 3. Category Performance Comparison.

While we do not claim these data offer a comprehensive evaluation of the categories, they demonstrate that certain guideline elements—such as user onboarding or risk communication—were especially relevant in more complex or newer application types.

4.2.3. Patterns of Success and Challenge

Through our analysis, we identified several recurring patterns of both successful and challenging implementations. OpenSea [91] and Aave [74], for example, demonstrated particularly effective approaches to the progressive disclosure of complex features, while MetaMask [75] set standards for transaction flow clarity. These successful patterns often centered around making complex blockchain operations more accessible through familiar interaction models.

However, several consistent challenges emerged across applications. Educational content was frequently separated from core functionality, feedback systems often failed to provide clear recovery paths, and technical terminology created a significant cognitive load for users. These challenges were particularly pronounced in applications dealing with complex financial operations or cross-chain interactions.

4.2.4. Framework Assessment

Our evaluation also provided insights into the effectiveness of our heuristic framework itself. While some heuristics proved to be strong predictors of usability issues (particularly Pattern Recognition and Transaction Management), others showed variable effectiveness across different application types. Most notably, we found overlapping coverage between User Understanding and Educational Experience heuristics, suggesting a need for refinement.

These findings provided valuable insights into the current state of Web3 usability and guided our subsequent refinement of the evaluation framework. The clear patterns of both success and challenge across different application categories suggested the need for more nuanced, context-specific evaluation criteria while maintaining a consistent core framework.

4.2.5. Framework Gaps and Limitations

Our systematic evaluation revealed several significant gaps in the current heuristic framework, providing crucial insights for refinement. These findings emerged from the practical application of the heuristics and the analysis of cases where the framework proved insufficient.

Structural Framework Issues

Analysis of guidelines application in heuristic format revealed several structural limitations in the current framework. Most notably, we found a significant overlap between user understanding (H1) and educational materials (H2), with evaluators frequently struggling to differentiate between these aspects during assessment. Similar redundancy appeared in status tracking criteria, which appeared across multiple sections, including wallet integration and safety features.

Context-Specific Requirements

The evaluation highlighted the framework's limitations in addressing application-specific needs. We found that safety and data control points, while crucial for DeFi applications and wallets, were often irrelevant or inappropriately weighted for other application types. Most notably:

- Wallet applications require specialized evaluation criteria for network management and transaction signing
- DeFi and NFT applications needed a specific focus on irreversible actions and risk communication

Technical Assessment Gaps

Significant gaps emerged in the framework's ability to assess technical aspects of Web3 applications:

- Only two applications (Aave [74] and Uniswap [98]) provided testnet functionality
- Wallet integration specifications lacked precision
- Privacy customization criteria proved unclear

Cognitive Load Considerations

The current framework proved insufficient in addressing the cognitive load aspects unique to Web3 applications:

- Complex DeFi interfaces often overwhelm users with information
- Multi-step processes lacked clear evaluation criteria
- Technical terminology created an additional cognitive burden

4.3. Framework Refinement

The analysis led to a complete restructuring of the evaluation framework, moving from a traditional three-level system (MVP, Standard, Full) to a matrix-based structure organized around five core categories.

4.3.1. Structural Changes

The new framework is organized into five main categories:

1. User Understanding and Mental Models
2. Interface Design
3. Wallet Integration
4. Data and Privacy
5. Value and Community

Each category progresses through three levels:

- Level 1: Foundation—Core functionality for basic Web3 interaction
- Level 2: Enhanced—Advanced features for experienced users
- Level 3: Professional—Enterprise-grade features and institutional support

4.3.2. Key Category Components

User Understanding and Mental Models

- Foundation: Basic Understanding, Integrated Education, Pattern Adoption
- Enhanced: Adaptive Learning, Technical Mastery
- Professional: Expert Features

Interface Design

- Foundation: State Visualization, Core Communication, Feedback Systems
- Enhanced: Advanced State Management, Rich Communication
- Professional: –

Wallet Integration

- Foundation: Connection Management, Transaction Design, Network Handling
- Enhanced: Multi-Wallet Support, Transaction Design
- Professional: –

Data and Privacy

- Foundation: Data Clarity, User Control
- Enhanced: Advanced Privacy
- Professional: Security Enhancement

Value and Community

- Foundation: Value Communication, Community Integration
- Enhanced: Governance Participation, Value Improvement
- Professional: –

4.3.3. Notable Framework Changes

The new framework introduces several significant improvements over its predecessor. We streamlined the categorization by reducing the main categories from nine to five, making it more focused and manageable. Additionally, we implemented a matrix presentation that clearly illustrates progression paths across different levels of implementation.

A key enhancement in the framework is its heightened attention to Web3-specific aspects, including the following:

- Cognitive load management in user understanding.
- Blockchain state visualization in interface design.
- Network handling in wallet integration.
- Data origin and permanence in privacy considerations.
- Token economics in a value proposition.

The refined structure allows for more explicit evaluation criteria while comprehensively covering essential Web3 application aspects. The intermediate version of the guidelines framework is presented in Appendix C.

4.4. Expert Evaluation Results

The expert evaluation sessions provided rich insights into the practical application of the guidelines and their effectiveness in supporting Web3 interface design. This section presents the key findings organized around three main themes: guideline utilization patterns, design approaches, and improvement opportunities.

4.4.1. Methodology Implementation Analysis

The execution of the expert evaluation methodology revealed several insights into the effectiveness of the planned approach and areas requiring refinement. While the core structure of the evaluation sessions remained consistent with the planned methodology, several notable variations emerged during implementation.

The implementation of the think-aloud protocol revealed varying levels of participant engagement. While some participants naturally verbalized their thought processes, others required periodic prompting to maintain consistent commentary. This variation in verbal feedback density suggests potential improvements in protocol introduction and ongoing facilitation techniques.

The multi-modal data collection strategy proved robust, successfully capturing the following:

- Session recordings documenting participant interactions.
- Design outputs through Figma artifacts.
- Verbal feedback through think-aloud protocols.
- Structured feedback through post-session interviews.

This comprehensive data collection enabled rich analysis while providing means for the triangulation of findings.

4.4.2. Guideline Utilization Patterns

The analysis revealed that experts predominantly approached the guidelines as a verification tool rather than an initial design reference (6 of 7 participants). This pattern manifested consistently across different expert backgrounds and expertise levels, with participants first relying on their experience to create designs and then consulting the guidelines to ensure comprehensive coverage of Web3-specific considerations.

A notable observation was the selective utilization of guideline sections. While Interface Design (7/7) and Wallet Integration (6/7) sections received significant attention, other sections, such as Community Integration, were often considered peripheral to basic wallet functionality. As one expert noted, "For me, it was natural to refer to the guidance and have a look if I've missed something" (P2), indicating a post-design verification approach rather than using guidelines as initial design principles.

4.4.3. Design Approaches and Solutions

The design task revealed consistent patterns in how experts approached Web3 interface challenges. For the onboarding screen (Figure 4), experts unanimously employed progressive disclosure principles, breaking down complex Web3 concepts into manageable steps. This approach typically manifested in three key areas:

1. Initial familiarization.
    - Utilization of familiar Web2 patterns.
    - Introduction of basic wallet concepts.
    - Progressive complexity introduction.
2. User education integration.
    - Step-by-step guidance.
    - Visual aids for complex concepts.
    - Context-specific help elements.

For transaction confirmation screens (Figure 5), experts focused on building trust through transparency and verification options. Common elements included the following:

- Clear transaction status indicators.
- Multiple verification options.
- External blockchain explorer integration.
- Comprehensive transaction details.
- Time and date information.

The consistent patterns in design solutions across experts suggest that certain Web3 interface patterns are becoming standardized, particularly in security communication and transaction confirmation. These patterns could form the basis for more prescriptive guidance in future iterations of the guidelines.

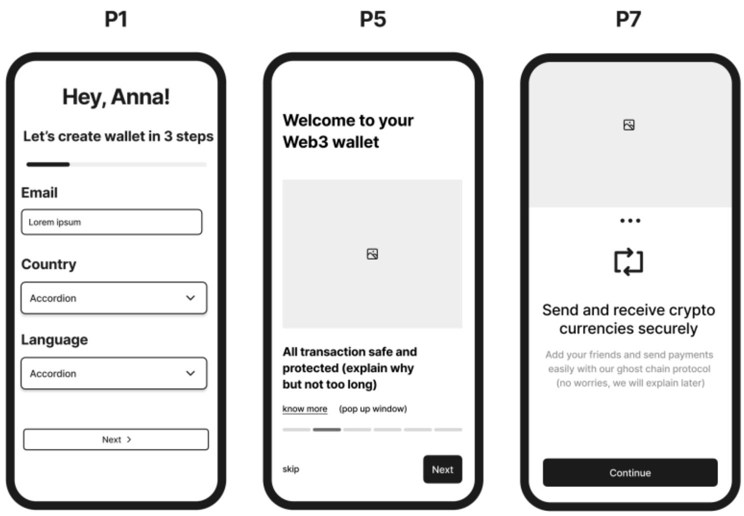

Figure 4. Sample results of the onboarding screen developed by participants.

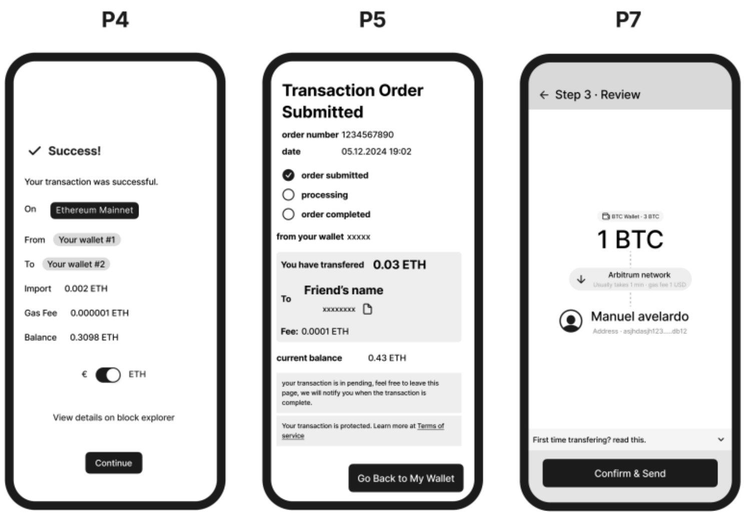

Figure 5. Sample results of the transaction confirmation screen developed by participants.

4.4.4. Improvement Opportunities

The evaluation revealed several areas where the guidelines could be enhanced to serve their intended purpose better. The current thematic organization, while comprehensive, could benefit from a more task-oriented structure. One participant observed, "Maybe for me, it's a little bit too much info" (P1), suggesting a need for better information hierarchy.

The expert evaluation revealed that while the guidelines comprehensively cover Web3 design considerations, their practical application could be improved through structural improvements and additional supporting materials. Experts identified two primary areas for guideline enhancement:

1. Information Density (6/7 experts).
2. Organizational Structure (5/7 experts).

4.5. Refinement of Guidelines

The expert evaluation findings led to several significant refinements of the framework of the guidelines to better align with observed design practices and expert needs. These refinements address both structural organization and content prioritization while maintaining comprehensive coverage of Web3 interface design considerations.

4.5.1. Structural Reorganization

The primary refinement involved restructuring the guidelines from a category-based to a task-flow-based organization, reflecting how designers approach Web3 interface development:

1. Onboarding Flow:
    - User Registration.
    - Wallet Creation Process.
    - Value Building.
    - Wallet Connection and Management.
    - Security Awareness Building.
    - Progressive Feature Introduction.
    - Trust Building.
    - Learning Integration.
    - Wallet Features.
    - Advanced Learning Integration.
    - Advanced Trust Building.
2. Transaction Flow:
    - Transaction Initiation and Confirmation.
    - Status Visualization and Updates.
    - Network Interaction Management.
    - Complex Transaction Management.
    - Multi-network Operations.
    - Advanced Security Features.
3. Settings and Configuration:
    - Privacy Controls and Preferences.
    - Network and Wallet Management.
    - Data Visibility and Control.
    - Improved Privacy Controls.
    - Configuration Options.
    - Advanced Trust Features.
4. Other Features:
    - Basic Governance Features.
    - Active Governance.
    - Improved Value Integration.
    - Professional Tools.

4.5.2. Implementation Hierarchy

Each task flow section maintains three distinct implementation levels, now more clearly defined:

1. Essential Implementation (Level 1):
    - Must-have features for basic functionality.
    - Core security and privacy requirements.
    - Fundamental user education elements.
    - Basic error handling and recovery.
2. Standard Implementation (Level 2):
    - Common pattern implementations.
    - Advanced user experience features.
    - Advanced security options.

- Extended functionality support.

3. Advanced Implementation (Level 3);
    - Institutional-grade features.
    - Complex operation support.
    - Professional tools integration.
    - Advanced customization options.

These refinements aim to better align the guidelines with observed design practices while maintaining comprehensive coverage of Web3 interface design considerations. The new structure supports both experienced designers using guidelines as verification tools and those requiring more detailed implementation guidance. The final version of the Web3 design guidelines framework is detailed in Appendix D.

4.6. Evolution of the Web3 Design Guidelines

The development of our Web3 design guidelines followed an iterative path, with each version responding to emerging insights and practical challenges encountered during evaluation. This evolution reflects a journey from theoretical organization to practical application, driven by systematic evaluation and expert feedback.

4.6.1. Initial Version (v1)

Our initial approach organized the guidelines into nine fundamental categories. Each category contained guidelines across three implementation levels (MVP, Standard Product, and Full Product), creating a detailed framework. However, the evaluation revealed several key limitations:

- Categories often overlapped, creating confusion about guideline placement.
- The hierarchy did not reflect actual design workflows.
- Implementation levels were not clearly distinguished in practice.
- Some categories proved more relevant than others, depending on the application type.

4.6.2. Intermediate Version (v2)

Responding to these challenges, we transformed the guidelines into a matrix framework with five core categories. This restructuring brought several improvements:

- Reduced overlap between categories.
- Clearer progression paths across implementation levels.
- Better integration of technical requirements.
- Improved consideration of cognitive load.

However, expert evaluation revealed that while more organized, this structure still faced practical challenges. Designers were jumping between different parts of the matrix to guide specific tasks, and some found the structure did not align with their typical development workflows.

4.6.3. Final Version (v3)

These insights led to the most significant transformation: restructuring the guidelines around four key task flows that mirror actual development processes. This structure proved particularly effective because it maintained comprehensive coverage while making the guidelines more actionable. Technical requirements became naturally integrated into relevant workflow stages, and teams could better understand how to phase and prioritize different features.

4.6.4. Key Transformations Across Versions

The evolution across versions can be summarized in two key areas:

1. Structural Evolution:
    - V1 → V2: From categories to matrix.
    - V2 → V3: From matrix to task flows.
    - Progressive simplification of navigation.
2. Content Organization:
    - V1: Broad categories with some overlap.
    - V2: Focused categories with clear boundaries.
    - V3: Task-oriented groupings with a practical focus.

This evolution demonstrates the value of iterative refinement in creating practical design tools. Each version built upon the strengths of its predecessor while addressing newly discovered limitations, ultimately creating a framework that bridges the gap between comprehensive coverage and practical implementation.

5. Discussion

5.1. Key Findings and Theoretical Implications

Our systematic evaluation revealed three fundamental insights about Web3 user experience design:

First, the primary usability challenges stem from the paradigm shift to decentralized, trustless environments. Users struggle with technical concepts like private key management and gas fees and, more fundamentally, developing new mental models for decentralized interactions. This aligns with Moniruzzaman's [22] findings about cognitive barriers in blockchain systems while extending their work to show how these challenges manifest across different application categories.

Second, we found a clear maturity gap between established and emerging Web3 applications. While platforms like OpenSea [91] and MetaMask [75] have developed effective patterns for progressive disclosure and transaction flow management, newer applications often struggle with fundamental interaction design. This suggests an ecosystem-wide need for standardized design patterns, supporting Ray's [8] argument for systematic approaches to Web3 UX design.

Third, our findings reveal a tension between technical complexity and user accessibility beyond simple UI/UX considerations. This extends Shin and Hwang's [28] work on trust in blockchain systems by demonstrating how interface design choices directly impact user trust and adoption potential.

5.2. Practical Implications

Our research has several important implications for Web3 designers and developers:

1. The evolution of our guidelines from category-based to task-flow organization reflects a crucial insight—Web3 interfaces are most effective when structured around user tasks rather than technical concepts. This approach helps bridge the gap between blockchain complexity and user understanding.
2. Our evaluation of successful applications revealed specific patterns for introducing complex blockchain concepts. For example, successful wallets like MetaMask [75] use a layered approach that achieves the following:
    - Introduces basic concepts during onboarding.
    - Reveals technical details progressively during relevant tasks.
    - Provides context-sensitive education throughout the user journey.

3. The high agreement among expert evaluators on specific design patterns suggests emerging standards for common interactions like wallet connection and transaction confirmation. Developers should consider adopting these patterns to reduce cognitive load across the ecosystem.

5.3. Addressing Research Questions

The evolution of these guidelines directly addressed our initial research questions. In regard to RQ1, our systematic evaluation revealed several key challenges:

- Complex technical concepts that users must understand (wallets, gas fees, smart contracts).
- Managing irreversible transactions and their implications.
- Balancing security requirements with usability.
- Providing appropriate feedback for blockchain operations.
- Helping users develop new mental models for decentralized interactions.

Considering the RQ2, we noticed that the evaluation of 25 Web3 applications revealed varying approaches across the ecosystem:

- Established platforms (like major NFT marketplaces and popular wallets) successfully employ progressive disclosure and simplified transaction flows.
- DeFi applications face challenges in explaining complex financial concepts.
- Most applications show room for improvement in error handling and recovery.

Our iterative development process led to four key task-based principles in response to RQ3:

- Structure interfaces around natural user workflows rather than technical concepts.
- Progressively introduce Web3 complexity through clear task flows.
- Integrate education and security naturally into user journeys.
- Maintain consistent feedback and status visualization throughout interactions.

These findings drove the evolution from our initial category-based guidelines to the final task-oriented framework, creating a practical tool that directly addresses the identified challenges while supporting proven solution patterns.

This evolution demonstrates the value of iterative refinement in creating practical design tools. Each version built upon the strengths of its predecessor while addressing newly discovered limitations, ultimately creating a framework that bridges the gap between comprehensive coverage and practical implementation. The final task-flow organization answers our research questions and provides designers with clear, actionable guidance for creating user-friendly Web3 interfaces.

5.4. Limitations and Future Work

While comprehensive, our study has several limitations that suggest directions for future research:

1. Sample Limitations:
    - Our selection of 25 applications, while diverse, may not capture all emerging trends.
    - Expert evaluations focused on current Web3 practitioners, potentially missing insights from mainstream UX perspectives.
    - The rapid evolution of Web3 technology means some findings may need regular updates.
2. Methodological Constraints:
    - The lack of longitudinal data limits our understanding of how these guidelines impact user adoption over time.

- The focus on interface design may not fully address the underlying technical constraints.
- The expert evaluation process could benefit from larger sample sizes in future iterations.

3. Future Research Directions:
    - Longitudinal studies tracking the impact of these guidelines on user adoption metrics.
    - Investigations of how emerging technologies (Layer 2, AI integration) affect UX requirements.
    - Research into how these guidelines apply to specific domains (DeFi, NFTs, social platforms).

Our planned evaluation of the guidelines through the Smart Fidget Toy project [102] represents a first step in this direction, potentially offering insights into how these principles apply to novel Web3 use cases and hardware interfaces.

As Web3 technologies evolve, future research must remain agile, adapting to new technical capabilities while focusing on user needs. Particular attention should be paid to emerging trends in cross-chain interactions, AI integration, and scalability solutions, as these developments may introduce new UX challenges and opportunities.

6. Conclusions

This study represents a significant step toward addressing the crucial user experience design challenge in Web3 applications. We have developed a comprehensive set of design guidelines that bridge the gap between theoretical understanding and practical implementation in Web3 interface design through a systematic approach combining a literature review, a heuristic evaluation of existing applications, and expert validation.

Our findings reveal both the progress and persistent challenges in the Web3 user experience. The refined guideline framework, organized around task flows rather than abstract categories, provides designers with practical, actionable guidance for creating more user-friendly Web3 interfaces. The three-tiered implementation structure (Essential, Standard, and Advanced) allows for the progressive enhancement in applications while ensuring fundamental usability requirements are met. This approach emphasizes progressive disclosure of complex blockchain concepts via integrated user education and support, clear visualization of system states, and enhanced trust through transparency.

The evolution of Web3 technologies continues to present new challenges and opportunities for user experience design. These guidelines must evolve as Layer 2 solutions, cross-chain interactions, and AI integration become more prevalent.

Despite these ongoing challenges, this study provides a strong foundation for creating more accessible and user-friendly Web3 applications. By following these guidelines, designers and developers can better address the unique challenges of blockchain-based interfaces while focusing on user needs and experiences.

The widespread adoption of Web3 technologies ultimately depends on creating interfaces that technical and non-technical users can navigate confidently. These guidelines represent a significant step toward that goal, providing a structured approach to designing interfaces that balance blockchain systems' technical requirements with users' practical needs.

As Web3 continues to evolve, we anticipate that these guidelines will serve as a living document, adapted and refined through practical application and further research. Through continued focus on user experience and systematic application of design principles, we can work toward a more inclusive and user-friendly decentralized web.

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Data Availability Statement: The data presented in this study are available at the request of the corresponding author (for privacy, legal, and ethical reasons).

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Appendix A

Web3 Design Guidelines v1

Level 1: MVP (Minimum Viable Product)

1. Core User Experience

1.1 User Understanding

- System adapts to different user expertise levels
- Acknowledge the lack of user knowledge as a barrier
- Address mistrust due to unfamiliarity
- Prepare answers to common concerns (e.g., safety, privacy)

1.2 Basic Education

- Provide easy-to-find educational materials
- Use plain language to explain concepts progressively
- Allow users to turn educational aids on or off

1.3 Familiar Patterns

- Use known patterns to reduce the learning curve
- Incorporate familiar elements from Web2
- Keep interactions consistent with web standards

2. Essential Interface Design

2.1 Basic UI Elements

- Maintain a decluttered and organized interface
- Keep fonts, colors, and shapes uniform
- Represent concepts thoughtfully with iconography
- Distinguish important data using color and font choices

2.2 Clear Communication

- Use clear, familiar terms consistently
- Avoid confusing technical language
- Translate machine data into human-friendly formats
- Use abridged versions of addresses and hashes

2.3 System Feedback

- Provide clear system statuses
- Keep users informed about ongoing processes
- Use progress indicators for longer operations

3. Onboarding and Navigation
3.1 First-Time Experience

- Aim for smooth and instant onboarding
- Offer simplified versions for beginners
- Guide users through the initial setup

3.2 Basic Interactions

- Keep actions efficient and intuitive
- Ensure easy access to main features
- Provide clear navigation paths

4. Wallet Integration
4.1 Basic Wallet Functions

- Prioritize compatibility with widely used wallets
- Provide straightforward wallet connection guidance
- Include essential transaction tracking

4.2 Security Foundations

- Implement basic security measures
- Guide users through the secure setup
- Explain basic security concepts

5. Transaction Management
5.1 Basic Transactions

- Present clear transaction information
- Show basic gas fee information
- Use human-readable data formats

5.2 Safety Measures

- Mark irreversible actions
- Provide basic transaction confirmations
- Show transaction status updates

6. Trust and Transparency
6.1 Basic Transparency

- Communicate data collection practices
- Explain blockchain interactions clearly
- Specify data sources and usage

6.2 Trust Building

- Implement basic security measures
- Explain privacy protections
- Maintain consistent communication

7. User Control
7.1 Data Control

- Provide basic data management options
- Allow for essential privacy settings

- Enable basic preference customization

7.2 Account Management

- Offer basic account controls
- Enable essential security settings
- Provide clear account status information

8. Community Features

8.1 Basic Engagement

- Provide basic community information
- Enable simple feedback mechanisms
- Show basic community metrics

9. Value and Innovation

9.1 Core Value

- Focus on essential user benefits
- Communicate clear value propositions
- Address basic user needs

Level 2: Standard Product

1. Enhanced User Experience

1.1 Advanced User Understanding

- Include comprehensive educational resources
- Create user-friendly guidelines by topic and skill level
- Provide contextual help systems

1.2 Enhanced Education

- Offer structured learning paths
- Provide interactive tutorials
- Create comprehensive documentation

1.3 Customization

- Enable feature toggles for different user types

2. Advanced Interface Design

2.1 Enhanced UI Elements

- Use purposeful animations and transitions

2.2 Enhanced Communication

- Implement multi-language support
- Provide context-sensitive help

2.3 Interactive Feedback

- Show detailed progress information
- Provide predictive suggestions
- Implement interactive tooltips
- Use advanced status indicators

3. Advanced Onboarding and Navigation

3.1 Enhanced Interactions

- Provide advanced search capabilities
- Implement filters and sorting

4. Advanced Wallet Integration

4.1 Multi-Wallet Support

- Support multiple wallet connections
- Enable wallet switching
- Provide detailed wallet information

4.2 Enhanced Security

- Provide security notifications

5. Advanced Transaction Management
5.1 Enhanced Transactions

- Show fees in multiple currencies
- Provide fee optimization options
- Enable batch transactions

5.2 Enhanced Safety

- Add multiple confirmation layers
- Provide transaction previews
- Show detailed gas estimations

6. Advanced Trust and Transparency
6.1 Enhanced Transparency

- Provide source code access
- Enable transaction history export
- Show detailed data flows

6.2 Enhanced Trust

- Use institutional endorsements

7. Advanced User Control
7.1 Enhanced Data Control

- Provide data export options
- Allow for granular permission control
- Implement usage analytics

7.2 Advanced Account Management

- Implement recovery options

8. Enhanced Community Features
8.1 Community Engagement

- Enable governance participation
- Provide community statistics

9. Advanced Value and Innovation
9.1 Enhanced Value

- Address edge cases

Level 3: Full Product
1. Comprehensive User Experience
1.1 Advanced User Understanding

- Implement feedback mechanisms for continuous improvement
- Conduct regular user research and analysis
- Provide personalized user journeys

1.2 Adaptive Education

- Provide personalized tutorials based on usage

- Enable advanced knowledge sharing

2. Professional Interface Design
2.1 Advanced Interaction Design

- Implement predictive UI behaviors
- Support complex interaction patterns

2.2 Global Communication

- Support complex localization needs
- Implement cultural adaptation
- Provide advanced terminology management
- Enable context-aware communication

2.3 Predictive Feedback

- Implement AI-powered suggestions
- Provide predictive error prevention

3. Advanced Workflows

- Provide advanced integration options

4. Wallet Integration
4.1 Advanced Security

- Implement scam detection mechanisms
- Provide automated security audits
- Support institutional security requirements

5. Advanced Transaction Systems
5.1 Professional Transactions

- Enable complex transaction planning
- Provide advanced fee optimization

6. Trust and Transparency
6.1 Full Transparency

- Provide comprehensive data tracking

6.2 Institutional Trust

- Enable community security audits

7. Complete User Control
7.1 Data Management

- Support complex permission systems
- Enable advanced policy management

8. Advanced Community Systems
8.1 Community Governance

- Enable complex voting systems

9. Enterprise Value and Innovation
9.1 Advanced Solutions

- Enable complex automation

Appendix B

Evaluation Template

Application Details

- Type:
- URL:
- Version/Date Evaluated:
- Wallet(s) Used:

Evaluation
1. User Understanding
H1: User Understanding and Adaptation
Description:

- System accommodates different expertise levels
- Addresses lack of user knowledge and mistrust
- Prepares answers for common concerns

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
H2: Educational Experience
Description:

- Easy-to-find educational materials
- Progressive concept explanation
- Configurable educational aids

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
2. Interface Design
H3: Pattern Recognition
Description:

- Familiar Web2 patterns
- Consistent web standards
- Clear navigation paths

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
H4: Essential UI Elements
Description:

- Decluttered interface organization
- Uniform visual elements
- Clear data representation

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme

Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
H5: Communication
Description:

- Consistent terminology
- Human-friendly data formats
- Clear status communication

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
H6: Feedback Systems
Description:

- Process status indicators
- Ongoing operation updates
- Clear system responses

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
3. Core Functions
H7: Wallet Integration
Description:

- Basic wallet compatibility
- Straightforward connection process
- Essential security measures

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
H8: Transaction Management
Description:

- Clear transaction information
- Basic fee transparency
- Status updates

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
H9: Safety Features
Description:

- Irreversible action warnings
- Basic confirmations

- Clear status tracking

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
4. Trust Building
H10: Basic Transparency
Description:

- Data collection clarity
- Blockchain interaction explanation
- Source specification

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
H11: Security Communication
Description:

- Basic security measures
- Privacy protection explanation
- Consistent updates

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
5. User Control
H12: Data Management
Description:

- Basic data controls
- Essential privacy settings
- Preference customization

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
6. Community and Value
H13: Community Interaction
Description:

- Basic community information
- Simple feedback systems
- Community metrics

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]

Screenshots/Evidence: [Insert or reference relevant screenshots]
H14: Value Delivery
Description:

- Essential benefits
- Clear value propositions
- Basic user needs

Severity Rating (0–4): 0—Not a problem 1—Cosmetic only 2—Minor problem 3—Major problem 4—Extreme
Specific Issues: [List any issues related]
Positive Aspects: [List any positive implementations related]
Screenshots/Evidence: [Insert or reference relevant screenshots]
Evaluation Summary

- Overall Score: [Average of all heuristic ratings]
- Critical Issues: [List any]
- Notable Strengths: [List any]

Appendix C

Web3 Design Guidelines v2

Appendix D

Web3 Design Guidelines v3

CATEGORY	LEVEL 1: ESSENTIAL *Core functionality and essential features required for basic Web3 interaction*	LEVEL 2: STANDARD IMPLEMENTATION *Advanced features and improved functionality for experienced users*	LEVEL 3: ADVANCED IMPLEMENTATION *Enterprise-grade features and institutional support capabilities*
Onboarding Flow	**User Registration** • Support primary wallet types • Show clear connection status • Handle connection errors • Adapt to different expertise levels • Acknowledge and address knowledge gaps • Maintain consistent interaction models • Provide clear recovery paths for errors **Trust Building** • Provide transparent data handling policies • Present clear recovery mechanisms **Value Building** • Explain Web3 benefits clearly • Show token utility • Present clear value propositions • Use familiar Web2 patterns where appropriate **Progressive Feature Introduction** • Measure and manage cognitive load during onboarding • Provide contextual learning elements • Explain concepts at point of need • Use progressive disclosure for complex features • Include success verification mechanisms • Provide human-readable formats for technical data **Wallet Connection and Management** • Show wallet connection status • Indicate network compatibility • Handle network errors • Provide clear affordances for blockchain actions **Wallet Creation Process** • Guide through seed phrase creation • Explain wallet security basics • Provide backup instructions • Include seed phrase verification • Support primary wallet types **Security Awareness Building** • Address Web3-specific concerns (security, privacy, irreversibility) • Show data permanence clearly • Explain data usage • Present privacy implications	**Learning Integration** • Offer context-aware help • Include educational materials • Support advanced terminology management • Provide predictive guidance **Wallet Features** • Support wallet switching • Enable advanced permissions • Include hardware wallet support • Show optimization opportunities	**Advanced Learning Integration** • Provide personalized learning paths • Include interactive tutorials • Track understanding progression • Enable customizable learning paths **Advanced Trust Building** • Display security certifications & audits • Show institutional endorsements
Transaction Flow	**Transaction Initiation and Confirmation** • Present clear signing requests • Explain transaction details • Show gas/fee estimates • Provide confirmation steps **Status Visualization and Updates** • Show network status clearly • Indicate blockchain state • Display transaction states • Indicate process status • Show network confirmations • Support in-app feedback system for wallet requests • Show human-readable transaction data **Network Interaction Management** • Support network switching • Show current network clearly • Indicate network requirements • Handle network errors	**Complex Transaction Management** • Support batch transactions • Enable gas optimization • Show detailed gas optimization strategies • Include contract interaction warnings • Support scheduling features **Multi-network Operations** • Handle multi-network scenarios • Display cross-chain interactions • Present advanced transaction states • Provide advanced error handling	
Settings & Configuration	**Privacy Controls and Preferences** • Enable privacy settings • Provide data visibility options • Allow preference customization **Network and Wallet Management** • Support primary wallet types • Show connection status • Handle connection errors • Support network switching **Data Visibility and Control** • Indicate data origin (on-chain, Oracle or off-chain) • Indicate where data will be written • Show data permanence clearly • Explain data usage • Enable basic permission management	**Improved Privacy Controls** • Enable granular permissions • Support data export • Include usage analytics • Provide audit trails **Configuration Options** • Support multiple languages • Include technical detail levels • Enable feature experimentation • Support advanced feature discovery **Advanced Trust Features** • Enable complex permission systems • Implement automated compliance checks	**Advanced Security Features** • Include fraud detection • Enable advanced auditing • Support institutional requirements • Provide security automation
Other Features	**Basic Governance Features** • Show community metrics • Enable basic participation • Display governance options and rights • Present contribution paths • Show community participation impact	**Active Governance** • Enable voting mechanisms • Show delegation options • Present proposal systems • Include discussion forums • Implement reputation systems **Improved Value Integration** • Support token economics • Show optimization options • Present advanced metrics • Include technical documentation	**Professional Tools** • Enable complex operations • Support advanced customization • Provide API access • Include security automation • Support institutional requirements

References

1. Gan, W.; Ye, Z.; Wan, S.; Yu, P.S. Web 3.0: The Future of Internet. In Proceedings of the ACM Web Conference 2023, Austin, TX, USA, 30 April–4 May 2023; pp. 1266–1275.
2. Hanswal, G.; Jain, S.; Thankachan, B. The Potential of Web3 for Shaping the Digital Landscape. *Int. J. Adv. Res. Sci. Commun. Technol.* **2023**, *3*, 27–35. [CrossRef]
3. Wan, S.; Lin, H.; Gan, W.; Chen, J.; Yu, P.S. Web3: The Next Internet Revolution. *IEEE Internet Things J.* **2023**, *11*, 34811–34825.
4. Zuo, Z. Development, Application, And Regulation of Web3.0. *Front. Bus. Econ. Manag.* **2023**, *9*, 22–27. [CrossRef]
5. Fenwick, M.; Jurcys, P. The Contested Meaning of Web3 and Why It Matters for (IP) Lawyers. *SSRN* 2022. [CrossRef]
6. Borgen, K.A.T. Web3 for Sensitive Data, Enterprise, Government, Private, and Permissioned Use. In Proceedings of the 2022 IEEE 1st Global Emerging Technology Blockchain Forum: Blockchain & Beyond (iGETblockchain), Irvine, CA, USA, 7–11 November 2022; pp. 1–6.
7. Wang, X.; Liu, Z.; Zhang, T. Flexible Sensing Electronics for Wearable/Attachable Health Monitoring. *Small* **2017**, *13*, 1602790. [CrossRef]
8. Ray, P.P. Web3: A Comprehensive Review on Background, Technologies, Applications, Zero-Trust Architectures, Challenges and Future Directions. *Internet Things Cyber-Phys. Syst.* **2023**, *3*, 213–248. [CrossRef]
9. Shadbolt, N.; Berners-Lee, T.; Hall, W. The Semantic Web Revisited. *IEEE Intell. Syst.* **2006**, *21*, 96–101. [CrossRef]
10. Abbate, J. *Inventing the Internet*; MIT Press: Cambridge, MA, USA, 2000; ISBN 978-0-262-51115-5.
11. Potts, J.; Rennie, E. Web3 and the Creative Industries: How Blockchains Are Reshaping Business Models. In *A Research Agenda for Creative Industries*; Edward Elgar Publishing: Cheltenham, UK, 2019; pp. 93–111. ISBN 978-1-78811-858-3.
12. Nakamoto, S. *Bitcoin: A Peer-to-Peer Electronic Cash System*; Scientific Research Publishing: Chengdu, China, 2008.
13. Buterin, V. A next generation smart contract & decentralized application platform. *White Pap.* **2014**, *3*, 1–36.
14. Wang, S.; Ouyang, L.; Yuan, Y.; Ni, X.; Han, X.; Wang, F.-Y. Blockchain-Enabled Smart Contracts: Architecture, Applications, and Future Trends. *IEEE Trans. Syst. Man Cybern. Syst.* **2019**, *49*, 2266–2277. [CrossRef]
15. Seven, S.; Yao, G.; Soran, A.; Onen, A.; Muyeen, S.M. Peer-to-Peer Energy Trading in Virtual Power Plant Based on Blockchain Smart Contracts. *IEEE Access* **2020**, *8*, 175713–175726. [CrossRef]
16. Khan, S.N.; Loukil, F.; Ghedira-Guegan, C.; Benkhelifa, E.; Bani-Hani, A. Blockchain Smart Contracts: Applications, Challenges, and Future Trends. *Peer-to-Peer Netw. Appl.* **2021**, *14*, 2901–2925. [CrossRef]
17. Metcalfe, W. Ethereum, Smart Contracts, DApps. In *Blockchain and Crypto Currency: Building a High Quality Marketplace for Crypto Data*; Yano, M., Dai, C., Masuda, K., Kishimoto, Y., Eds.; Springer: Singapore, 2020; pp. 77–93. ISBN 9789811533761.
18. Baird, K.; Jeong, S.; Kim, Y.; Burgstaller, B.; Scholz, B. The Economics of Smart Contracts. *arXiv* **2019**, arXiv:1910.11143.
19. Jumnongsaksub, S. Reducing Smart Contract Runtime Errors on the Ethereum Blockchain. Mater's Thesis, Chulalongkorn University, Bangkok, Thailand, 2020.
20. Genet, T.; Jensen, T.; Sauvage, J. Termination of Ethereum's Smart Contracts. In Proceedings of the 17th International Joint Conference on e-Business and Telecommunications (ICETE 2020), Paris, France, 8–10 July 2020; pp. 39–51.
21. Wu, K.; Ma, Y.; Huang, G.; Liu, X. A First Look at Blockchain-Based Decentralized Applications. *Softw. Pract. Exp.* **2019**, *51*, 2033–2050. [CrossRef]
22. Moniruzzaman, M.; Chowdhury, F.; Ferdous, M.S. Examining Usability Issues in Blockchain-Based Cryptocurrency Wallets. In *Proceedings of the Cyber Security and Computer Science*; Bhuiyan, T., Rahman, M.M., Ali, M.A., Eds.; Springer International Publishing: Cham, Switzerland, 2020; pp. 631–643.
23. Eskandari, S.; Clark, J.; Barrera, D.; Stobert, E. A First Look at the Usability of Bitcoin Key Management. In Proceedings of the 2015 Workshop on Usable Security, San Diego, CA, USA, 8 February 2015.
24. Bernal Bernabe, J.; Canovas, J.L.; Hernandez-Ramos, J.L.; Torres Moreno, R.; Skarmeta, A. Privacy-Preserving Solutions for Blockchain: Review and Challenges. *IEEE Access* **2019**, *7*, 164908–164940. [CrossRef]
25. Ioniță, A. *The Politics for Digital Transformation: A Prescriptive Approach*; "DIMITRIE CANTEMIR" University: Tîrgu Mureș, Romania, 2022.
26. Ghosh, A.; Gupta, S.; Dua, A.; Kumar, N. Security of Cryptocurrencies in Blockchain Technology: State-of-Art, Challenges and Future Prospects. *J. Netw. Comput. Appl.* **2020**, *163*, 102635. [CrossRef]
27. Shin, D.; Hwang, Y. The Effects of Security and Traceability of Blockchain on Digital Affordance. *Online Inf. Rev.* **2020**, *44*, 913–932. [CrossRef]
28. Shin, D.D.H. Blockchain: The Emerging Technology of Digital Trust. *Telemat. Inform.* **2019**, *45*, 101278. [CrossRef]
29. Politou, E.; Casino, F.; Alepis, E.; Patsakis, C. Blockchain Mutability: Challenges and Proposed Solutions. *IEEE Trans. Emerg. Top. Comput.* **2021**, *9*, 1972–1986. [CrossRef]
30. Gangwal, A.; Gangavalli, H.R.; Thirupathi, A. A Survey of Layer-Two Blockchain Protocols. *J. Netw. Comput. Appl.* **2022**, *209*, 103539.

31. Neiheiser, R.; Inácio, G.; Rech, L.; Montez, C.; Matos, M.; Rodrigues, L. Practical Limitations of Ethereum's Layer-2. *IEEE Access* **2023**, *11*, 8651–8662. [CrossRef]
32. Mohanty, D.; Anand, D.; Aljahdali, H.M.; Villar, S.G. Blockchain Interoperability: Towards a Sustainable Payment System. *Sustainability* **2022**, *14*, 913. [CrossRef]
33. Harris, C.G. Cross-Chain Technologies: Challenges and Opportunties for Blockchain Interoperability. In Proceedings of the 2023 IEEE International Conference on Omni-layer Intelligent Systems (COINS), Berlin, Germany, 23–25 July 2023; pp. 1–6.
34. Madine, M.; Salah, K.; Jayaraman, R.; Al-Hammadi, Y.; Arshad, J.; Yaqoob, I. appXchain: Application-Level Interoperability for Blockchain Networks. *IEEE Access* **2021**, *9*, 87777–87791. [CrossRef]
35. Badr, Y. On the Integration of Artificial Intelligence and Blockchains 3.0: Prospects and Challenges. In Proceedings of the 2021 IEEE 18th International Conference on Software Architecture Companion (ICSA-C), Stuttgart, Germany, 22–26 March 2021; p. 120.
36. Bouachir, O.; Aloqaily, M.; Karray, F.; Elsaddik, A. AI-Based Blockchain for the Metaverse: Approaches and Challenges. In Proceedings of the 2022 Fourth International Conference on Blockchain Computing and Applications (BCCA), San Antonio, TX, USA, 5–7 September 2022; pp. 231–236.
37. Guergov, S.; Radwan, N. Blockchain Convergence: Analysis of Issues Affecting IoT, AI and Blockchain. *Int. J. Comput. Inf. Manuf. (IJCIM)* **2021**, *1*, 1–17. [CrossRef]
38. Cong, L.W.; Tang, K.; Wang, Y.; Zhao, X. *Inclusion and Democratization Through Web3 and DeFi? Initial Evidence from the Ethereum Ecosystem*; National Bureau of Economic Research: Cambridge, MA, USA, 2022.
39. Ogunyemi, A.A.; Lamas, D.; Lárusdóttir, M.K.; Loizides, F. A Systematic Mapping Study of HCI Practice Research. *Int. J. Hum.-Comput. Interact.* **2019**, *35*, 1461–1486. [CrossRef]
40. Moreira Da Rosa, D.; Selbach Silveira, M. May the Patterns Be with You: A Framework for HCI Patterns Development. *IxD&A* **2022**, *54*, 175–208. [CrossRef]
41. Cruz-Benito, J.; García-Peñalvo, F.J.; Therón, R. Analyzing the Software Architectures Supporting HCI/HMI Processes through a Systematic Review of the Literature. *Telemat. Inform.* **2019**, *38*, 118–132. [CrossRef]
42. Subramanian, S.; Skjæret-Maroni, N.; Dahl, Y. Systematic Review of Design Guidelines for Full-Body Interactive Games. *Interact. Comput.* **2020**, *32*, 367–406. [CrossRef]
43. Zaphiris, P.; Kurniawan, S.; Ghiawadwala, M. A Systematic Approach to the Development of Research-Based Web Design Guidelines for Older People. *Univ. Access Inf. Soc.* **2007**, *6*, 59–75. [CrossRef]
44. Lai, Y.; Yang, J.; Liu, M.; Li, Y.; Li, S. Web3: Exploring Decentralized Technologies and Applications for the Future of Empowerment and Ownership. *Blockchains* **2023**, *1*, 111–131. [CrossRef]
45. Murray, A.; Kim, D.; Combs, J. The Promise of a Decentralized Internet: What Is Web3 and How Can Firms Prepare? *Bus. Horiz.* **2023**, *66*, 191–202. [CrossRef]
46. Sadowski, J.; Beegle, K. Expansive and Extractive Networks of Web3. *Big Data Soc.* **2023**, *10*, 20539517231159629. [CrossRef]
47. Why Design Is the Killer App for Crypto. Available online: https://www.coinbase.com/blog/why-design-is-the-killer-app-for-crypto (accessed on 2 September 2024).
48. Teruel, M.A.; Trujillo, J. Easing ÐApp Interaction for Non-Blockchain Users from a Conceptual Modelling Approach. *Appl. Sci.* **2020**, *10*, 4280. [CrossRef]
49. Gabrielli, S.; Rizzi, S.; Mayora, O.; More, S.; Pérez Baun, J.C.; Vandevelde, W. Multidimensional Study on Users' Evaluation of the KRAKEN Personal Data Sharing Platform. *Appl. Sci.* **2022**, *12*, 3270. [CrossRef]
50. Große, N.; Möller, F.; Schoormann, T.; Henke, M. Designing Trust-Enabling Blockchain Systems for the Inter-Organizational Exchange of Capacity. *Decis. Support Syst.* **2024**, *179*, 114182. [CrossRef]
51. Froehlich, M.; Waltenberger, F.; Trotter, L.; Alt, F.; Schmidt, A. Blockchain and Cryptocurrency in Human Computer Interaction: A Systematic Literature Review and Research Agenda. In Proceedings of the 2022 ACM Designing Interactive Systems Conference, Virtual Event, Australia, 13–17 June 2022; pp. 155–177.
52. Cila, N.; Ferri, G.; de Waal, M.; Gloerich, I.; Karpinski, T. The Blockchain and the Commons: Dilemmas in the Design of Local Platforms. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, Honolulu, HI, USA, 25–30 April 2020; pp. 1–14.
53. Murray-Rust, D.; Elsden, C.; Nissen, B.; Tallyn, E.; Pschetz, L.; Speed, C. Blockchain and Beyond: Understanding Blockchains Through Prototypes and Public Engagement. *ACM Trans. Comput.-Hum. Interact.* **2023**, *29*, 1–73. [CrossRef]
54. Pschetz, L.; Dixon, B.; Pothong, K.; Bailey, A.; Glean, A.; Soares, L.L.; Enright, J.A. Designing Distributed Ledger Technologies for Social Change: The Case of CariCrop. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, Honolulu, HI, USA, 25–30 April 2020; pp. 1–12.
55. Yu, Y.; Sharma, T.; Das, S.; Wang, Y. "Don't Put All Your Eggs in One Basket": How Cryptocurrency Users Choose and Secure Their Wallets. In Proceedings of the CHI Conference on Human Factors in Computing Systems, Honolulu, HI, USA, 11–16 May 2024; pp. 1–17.

56. Chen, Y.-P.; Ko, J.-C. CryptoAR Wallet: A Blockchain Cryptocurrency Wallet Application That Uses Augmented Reality for On-Chain User Data Display. In Proceedings of the 21st International Conference on Human-Computer Interaction with Mobile Devices and Services, Taipei, Taiwan, 1–4 October 2019; pp. 1–5.
57. Chen, Y.-P.; Ko, J.-C. The Impact of AR Filter Combines Blockchain Virtual Online Pets and Brings Blockchain into Our Lives. In Proceedings of the 2020 IEEE International Conference on Consumer Electronics—Taiwan (ICCE-Taiwan), Taoyuan, Taiwan, 28–30 September 2020; pp. 1–2.
58. Zeng, W.-X.; Yang, W.-H.; Pan, C.-L.; Ko, J.-C.; Lung, C.-H.; Tsao, H.-Y. WANA Wallet: The Application Design of Currency Wallets with Transaction Entertainment and Socialization Capital and Display Functions. In Proceedings of the 2022 IEEE International Conference on Consumer Electronics—Taiwan, Taipei, Taiwan, 6–8 July 2022; pp. 537–538.
59. Froehlich, M.; Kobiella, C.; Schmidt, A.; Alt, F. Is It Better With Onboarding? Improving First-Time Cryptocurrency App Experiences. In *Proceedings of the 2021 ACM Designing Interactive Systems Conference*; Association for Computing Machinery: New York, NY, USA, 2021; pp. 78–89.
60. Kwon, K.; Han, S.H.; Jang, H.; Kim, J.H. Usability in a Token-Based Ecosystem. In Proceedings of the Advances in Usability, User Experience, Wearable and Assistive Technology; Ahram, T.Z., Falcão, C.S., Eds.; Springer International Publishing: Cham, Switzerland, 2021; pp. 880–885.
61. Glomann, L.; Schmid, M.; Kitajewa, N. Improving the Blockchain User Experience—An Approach to Address Blockchain Mass Adoption Issues from a Human-Centred Perspective. In *Proceedings of the Advances in Artificial Intelligence, Software and Systems Engineering*; Ahram, T., Ed.; Springer International Publishing: Cham, Switzerland, 2020; pp. 608–616.
62. Ko, E. DApps & DAOs in DeFi: A Comparative UX Study of Aave and Compound. Available online: https://bootcamp.uxdesign.cc/dapps-daos-in-defi-a-comparative-ux-study-of-aave-and-compound-546c87dc6277 (accessed on 6 September 2024).
63. Web3 Design Principles. Available online: https://www.web3designprinciples.com/ (accessed on 6 September 2024).
64. UX and WEB3 Design Guide—The Top Challenges of UX/UI Design in Blockchain and How to Tackle Them. Available online: https://www.pixelsandsense.com/guides/ux-and-web3-design-guide-the-top-challenges-of-ux-ui-design-in-blockchain-and-how-to-tackle-them (accessed on 12 August 2024).
65. Oluwasegun. User Experience on Web 3.0—Designing the Future of the Web. *Bootcamp*. 2021. Available online: https://medium.com/design-bootcamp/user-experience-on-web-3-0-designing-the-future-of-the-web-b2054d9a0d23 (accessed on 31 October 2024).
66. Benji, T. Family Values. Available online: https://benji.org/family-values (accessed on 31 October 2024).
67. Crabb, J. 7 Heuristics for Web3 Design. Available online: https://web3ux.design/7-heuristics-for-web3-design (accessed on 31 October 2024).
68. Consensys MetaMask Delegation Toolkit Launches to Re-Imagine Web3 User Experience. Available online: https://consensys.io/blog/metamask-delegation-toolkit-launches-to-re-imagine-web3-user-experience (accessed on 31 October 2024).
69. Gnanam, S. Future of UX Design with Web3 | LinkedIn. Available online: https://www.linkedin.com/pulse/future-ux-design-web3-sivaprakasam-gnanam/ (accessed on 31 October 2024).
70. Mills, S.B. Blockchain Design Principles. *IBM Design*. 2017. Available online: https://medium.com/design-ibm/blockchain-design-principles-599c5c067b6e (accessed on 31 October 2024).
71. Crypto Reserach & Design Lab CRADL Report—UX in Cryptocurrency. Available online: https://docs.google.com/presentation/d/1s2OPSH5sMJzxRYaJSSRTe8W2iIoZx0PseIV-WeZWD1s/preview?slide=id.g137ca61f5de_0_447&usp=embed_facebook (accessed on 31 October 2024).
72. Jason, K. Web 3.0 Design Principles. Available online: https://www.figma.com/file/tsOJL25Z8Cy58hewZxLEsE/Web-3.0-Design-Principles-Community (accessed on 31 October 2024).
73. beltran Web3 Design Principles. *Medium*. 2018. Available online: https://medium.com/@lyricalpolymath/web3-design-principles-f21db2f240c1 (accessed on 31 October 2024).
74. Aave—Open Source Liquidity Protocol. Available online: https://app.aave.com/ (accessed on 26 December 2024).
75. MetaMask Wallet. Available online: https://metamask.io (accessed on 10 June 2024).
76. Brave Browser Download. Available online: https://brave.com/download/ (accessed on 26 December 2024).
77. Braavos Wallet—The Most Advanced Starknet Wallet. Available online: https://braavos.app/ (accessed on 26 December 2024).
78. Cerebrum DAO—Brains Helping Brains. Available online: https://www.cerebrumdao.com/ (accessed on 26 December 2024).
79. ChainGPT—Unleash The Power of Blockchain AI. Available online: https://www.chaingpt.org/ (accessed on 26 December 2024).
80. CitaDAO. Available online: https://citadao.io// (accessed on 26 December 2024).
81. CryptoKitties CryptoKitties | Collect and Breed Digital Cats! Available online: https://www.cryptokitties.co (accessed on 26 December 2024).
82. DappBack. Available online: https://dappback.com/ (accessed on 26 December 2024).
83. Welcome to Decentraland. Available online: https://decentraland.org/ (accessed on 26 December 2024).
84. Exchange.Art. Available online: https://exchange.art/ (accessed on 26 December 2024).

85. GMX | Decentralized Perpetual Exchange. Available online: https://app.gmx.io/#/trade (accessed on 26 December 2024).
86. Ronin Ronin Wallet. Available online: https://skymavis.com/ (accessed on 26 December 2024).
87. HairDAO. Available online: https://www.hairdao.xyz/ (accessed on 26 December 2024).
88. Mavis Market | Home. Available online: https://marketplace.skymavis.com (accessed on 26 December 2024).
89. Mirror. Available online: https://mirror.xyz/ (accessed on 26 December 2024).
90. Orb Social on Lens Protocol. Available online: https://apps.apple.com/ru/app/orb-social-on-lens-protocol/id1638461963?l=en-GB (accessed on 26 December 2024).
91. OpenSea OpenSea, the Largest NFT Marketplace. Available online: https://opensea.io/ (accessed on 26 December 2024).
92. Paragraph. Available online: https://paragraph.xyz/ (accessed on 26 December 2024).
93. Phaver. Available online: https://apps.apple.com/ru/app/phaver/id1516296591?l=en-GB (accessed on 26 December 2024).
94. Pixels: An Infinite World of Endless Adventure. Available online: https://play.pixels.xyz/ (accessed on 26 December 2024).
95. Snapshot. Available online: https://snapshot.box/#/ (accessed on 26 December 2024).
96. StarkDefi. Available online: https://app.starkdefi.com (accessed on 26 December 2024).
97. Sweat Wallet. Available online: https://apps.apple.com/us/app/sweat-wallet/id1619316571 (accessed on 26 December 2024).
98. Uniswap Interface. Available online: https://app.uniswap.org/ (accessed on 26 December 2024).
99. Trust: Crypto & Bitcoin Wallet. Available online: https://apps.apple.com/ru/app/trust-crypto-bitcoin-wallet/id1288339409?l=en-GB (accessed on 26 December 2024).
100. Nielsen, J.; Landauer, T.K. A Mathematical Model of the Finding of Usability Problems. In Proceedings of the INTERACT'93 and CHI'93 Conference on Human Factors in Computing Systems, Amsterdam, The Netherlands, 24–29 April 1993; pp. 206–213.
101. Method; Lorman, C.; Sharpe, T. Paper Wireframe Kit. Available online: https://www.figma.com/community/file/1075811850250564922/paper-wireframe-kit (accessed on 26 December 2024).
102. Bobrova, P.; Perego, P.; Boiano, R. Design and Development of a Smart Fidget Toy Using Blockchain Technology to Improve Health Data Control. *Sensors* **2024**, *24*, 6582. [CrossRef] [PubMed]