A First Look at the Usability of Web3 DApps

***Abstract*—While the usability literature has considered both web 2.0 web services, as well as cypto-currencies like Bitcoin, web3 is more than the sum of these parts. Web3 decentralized applications (DApps) deploy a unique model that creates new usability challenges, security risks to user funds, and privacy risks to user data. In this "vision" paper, we build a case that web3 needs attention from the usability community. We report on a preliminary study, using expert evaluation, to identify usability challenges across 50 popular Ethereum DApps found 'in the wild,' used alongside the popular wallet MetaMask. Our evaluation uncovers four common usability challenges impacting users' ability to make informed decisions, and points to opportunities for future user studies and areas for improvement.**

I. Introduction

When Ethereum introduced its vision for smart contracts that can be executed on a blockchain, user interfaces had to be rethought. In contrast to Bitcoin, Ethereum users are no longer merely making payments to a receiving address; they are interacting in arbitrary ways with decentralized applications (DApps) to perform more complex tasks like trading assets, establishing loans, bidding in auctions, and registering domain names. Furthermore, new DApps emerge too frequently for standalone wallet software to be customized for specific DApps. The idea that users might transact with smart contracts in a 'raw' way, by manually supplying a contract address, function to be run, and parameters to the function, was an obvious non-starter for non-expert users.

A. A Tangled Web3

The solution is what we now call web3 (see Figure 1). A DApp augments the smart contract with a companion website, accessible over the standard internet, which provides a user interface and mostly abstracts away the technical details of the contract. The connection between the website and the blockchain is convoluted however, hence the need for a usability analysis. Websites typically pass scripts to the user and the website, now running client-side, will interact with third party APIs to fetch up-to-date blockchain data that is general to all users. To customize the content for the specific user, the website does not maintain accounts server-side for its users, as in web 2.0. Instead the user is expected to run a standalone client, called a wallet (*e.g.,* MetaMask). After authorization, the wallet will supply the user's addresses to the website, and the website can propose blockchain actions to the wallet to present to the user for signature.

In summary, (i) users interact with a website first, rather than their wallet; (ii) after user authorization, the website and wallet can pass data between them; (iii) the wallet is agnostic about what the DApp is or does; (iv) all authorizations are done by the user in the wallet software; and (v) users will be asked to sign transactions in their wallet that they, and the wallet itself, will not 'understand,' instead relying on the trustworthiness of the website proposing the transaction.

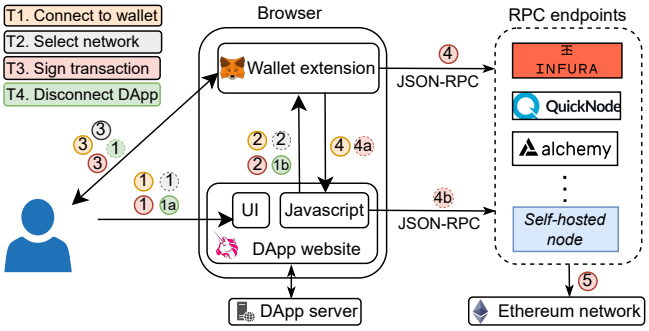


Fig. 1: Overview of four core tasks in web3. In task 1 (T1), the user selects "connect wallet" on the DApp (1) which requests the user's account address (2); the wallet obtains user approval (3) and returns the address (4). In T2, the user selects a blockchain network on the DApp (1̄) which triggers the wallet (2̄) to prompt the user to switch network (3); alternatively, the user can directly switch network on the wallet. In T3, the user initiates a transaction on the DApp (1) which sends it to the wallet (2); the wallet prompts the user for approval (3) and if approved, the wallet sends its proof to an Ethereum node via JSON-RPC APIs (4) which is then broadcast to the Ethereum network (5); alternatively, the proofs could be routed through the DApp (4a) before reaching the network (4b). In T4, the user selects "disconnect wallet" on the DApp (1) which asks the wallet to revoke its permissions (2); alternatively, the user can directly disconnect on the wallet (1̄).

B. Literature Review

Web3 is a security-usability subject as malicious DApps exploit the complex architecture of web3 to deceive users into granting permissions to their data and steal any funds they own through their web3 wallet [1], [2]. Web3 wallets inform users about fraud with warnings and prompts, but recent attacks [3], [4], [5] show that attacks continue to work.

Starting at USEC 2015 [14], numerous studies on Bitcoin usability have been conducted [15], [16], [17], [18], as well as generic blockchain technology [19], [20], [21], with one focus on wallet software [22] finding misinformed mental models due to an over-reliance on understanding of traditional web 2.0 systems. However we have argued web3 is more complex than a simple merge of Bitcoin concepts with web 2.0 concepts.

For Web3 specifically, we only found two relevant studies. Panicker et al. [6] focus on token transfers, which is the most Bitcoin-esque subset of web3, and does not explore DApps. At CHI 2024, Si et al. [1] focused on user perceptions,

utilizing interviews with participants, and finding concerns about vulnerable contracts, social engineering attacks, and other types of fraud.

C. Research Gap and Vision

The "vision" of our paper is to draw attention to DApps themselves and the wallet software used to interact with them, examining the interfaces, prompts, and cues which guide users through security- and privacy-sensitive tasks, looking for usability pitfalls that can lead users to make dangerous errors. To build a case that this is worth attention, we conduct a preliminary study. We identify 50 DApps 'in the wild' and conduct a cognitive walkthrough [8] of four core tasks with each DApp. After reviewing our findings, we identify four high-priority usability challenges in current interfaces based on our evaluations, and set forward a research agenda for exploring them in future studies.

II. Background

In web 2.0, apps are designed with a front-end website associated with a centralized back-end server and maintained by the website owner. Web3 redesigns this structure by replacing centralized services with a blockchain—a network of anonymous validators that store and run programs in exchange for financial rewards (referred to as "gas" fees).[1] Program logic is defined into *contracts* which run on a virtual environment called the Ethereum Virtual Machine (EVM). We discuss related aspects next. Figure 1 illustrates the web3 components involved in common tasks performed by users of DApps.

A. Wallet-DApp interaction

The primary mode for user authorizations for DApps is through wallets typically installed as browser extensions. Wallets such as MetaMask inject the Ethereum Provider API [10] into every website visited by the user, enabling the sites to discover wallets (e.g., through injected fields such as *window.provider.isMetaMask* [11]) and to create wallet prompts for approval to trigger contracts. DApps can also use other Ethereum methods [12] to send requests to the wallet for account addresses (*eth_requestAccounts*) and transaction requests (*eth_sendTransaction*), which are prompted to the user for approval.

B. EVM blockchains

Another feature of web3 is its scalability enabled by individual blockchains with distinct features (e.g., lower gas fees, and faster transactions).[2] These blockchains, also referred to as *sidechains* and *Layer 2* (L2) chains, run in parallel to the main Ethereum blockchain (L1) but adhere to Ethereum standards, so wallet software can interoperate with only a chain ID (unique identifier for the blockchain) and the Remote Procedure Call (RPC) URL (address of the remote server which acts as the gateway for the DApp to access the blockchain nodes). Many DApps integrate with multiple chains to support transactions across the ecosystem.

C. RPC endpoints

DApps and wallets rely on RPC endpoints[3] to exchange transaction data with EVM networks, using the standard JSON-RPC API [12]. For instance, MetaMask relies on Infura as its default endpoint [13]; note that these separate services are both owned by the same entity. These endpoints relate to different privacy implications, e.g., some providers maintain logs of user data transmitted through their servers while others state that they do not collect any user data. Thus, it is important for users to choose endpoints that align with their privacy preferences.

III. Methodology

A cognitive walkthrough [8] is a usability evaluation methodology often employed first to establish a priority list of usability issues to be considered with other methods. A dual expert (knowledgeable in both usability and in the domain of study—web3, in our case) evaluates if users with a specific persona (*e.g.,* no prior familiarity) can successfully use an application interface and complete a set of core tasks without violating a set of guidelines. For our study, we assume that users are comfortable with web 2.0 websites and browser extensions. We also assume basic familiarity with blockchain user interfaces, e.g., gained from bitcoin wallets that have existed before web3 DApps. Two evaluators independently generated an initial list of tasks users perform on web3 DApps. Then we discussed each task and whether a similar task has been studied in the past (*e.g.,* as part of bitcoin wallet evaluation) and agreed to focus on tasks unique to web3. We excluded one-time tasks (such as setting up an Ethereum wallet) and decided to focus on frequent tasks users need to perform across DApps. Our final list of core tasks included:

- T1. Connect MetaMask wallet to a given DApp website.
- T2. Configure wallet to connect to a desired blockchain network (if it is not already on it). This network has to be supported by the DApp to perform transactions; the supported networks may be different on each DApp.
- T3. Conduct an operation of the DApp site that does require wallet approval, configure and sign the transaction, understand and avoid risks. Covers token balances, gas fees, approvals, signature, confirming transaction, etc.
- T4. Revert, to the extent possible, any past interactions with the DApp including disconnecting the wallet and revoking permissions.

Fig. 1 shows the workflow of these tasks. We perform walkthroughs by simulating step-by-step user actions in each core task and asking ourselves whether the interface satisfied a list of usability guidelines. We draw our guidelines directly from the established usable security literature—specifically past studies of Bitcoin [14], [23]. We repeat verbatim:

[1] In practice, much of web3 traffic relies on services resembling centralization (cf. [9])

[2] As of Sept 2024, 1,061 blockchains as per https://chainlist.org/

[3] https://rpc.info/

G1. Users should be aware of the steps they have to perform to complete a core task.
G2. Users should be able to determine how to perform these steps.
G3. Users should know when they have successfully completed a core task.
G4. Users should be able to recognize, diagnose, and recover from non-critical errors.
G5. Users should not make dangerous errors from which they cannot recover.
G6. Users should be comfortable with the terminology used in any interface dialogues or documentation.
G7. Users should be sufficiently comfortable with the interface to continue using it.
G8. Users should be aware of the application's status at all times.

A walkthrough allows for an evaluation across a large number of DApps, in contrast to time-limited and costly user studies. During initial analysis, the two evaluators performed walkthroughs on different DApps to identify problematic areas and inform further walkthroughs of DApps in our full dataset. After refinement based on this analysis, the main researcher evaluated each of the top 50 DApps listed on *DAppRadar*,[4] ranked by the total value of assets held under the DApp's contract over a 30-day period (Nov 2024). We used the MetaMask wallet for these tasks.

A. A Sample Walkthrough

For space considerations, we do not present the full details of each walkthrough of 4 tasks over 50 DApps. Instead, we present one representative sample walkthrough to illustrate what the methodology looks like, and then we present our overall results, based on all walkthroughs, in the next section. The sample is the (T3) transaction approval task in the DApp Uniswap [24], a decentralized exchange service on Ethereum allowing users to exchange one type of (ERC-20) token for another. We assume the persona of a typical web3 user who owns one or more tokens, uses a common wallet such as MetaMask, and has basic understanding about Ethereum tokens and transactions. For this task, we also assume the user has already connected their wallet to Uniswap (T1) and successfully switched to a target network (T2).

The swap page on Uniswap site prompts the user to select the tokens and the exchange amounts. After selecting a token (ETH) to sell, the prompt shows the available wallet balance and an option to use the maximum amount. We input an arbitrary amount to sell, and select to buy USDT using the token search option. Searching "usdt" displayed three entries of which one was marked with an warning symbol. When selected, a prompt cautioned that the token was not among frequently traded tokens. While only one entry was marked with this symbol, two entries triggered the same warning prompt. Although these warnings aim to alert users about potential scams, conflicting cues likely cause confusion (violating G6-G7) and reduce the effectiveness of warnings.

Uniswap triggers a wallet prompt with details about the transaction. At the top of the prompt, a small icon beside the contract address displays a generic message prompting users to verify before trusting the contract. This violates G2 as there is no guidance on how to verify. The prompt also includes a section with predictions about the resulting balance changes, however this is not guaranteed as indicated within an icon. We discuss this issue further in Sec. IV-C. The prompt also includes estimated gas fees and an option to set a limit on the maximum fee. This option (in a secondary prompt) lists four choices with different limits and processing times (options with lower fees tradeoff on longer wait times).

After selecting "low" gas and submitting the transaction, the wallet notified that the transaction had failed without any description. An external link from the wallet showed the error output directly from the contract, however this message is ambiguous with no recovery instructions. This violates G4. Uniswap's troubleshooting guide [25] lists potential reasons for transaction failures including possible issues caused by low gas limits, although users cannot be expected to find such resources for each transaction failure.[5] The DApp/wallet interface can address these issues by explaining transaction failures and providing instructions on possible recovery options.

B. Limitations

Our findings cover 50 popular DApps with MetaMask which may not be representative of other DApps and wallets. We also do not cover mobile wallets and DApps accessed through mobile browsers. We evaluated a set of four core tasks which does not cover other tasks users might perform on DApps, such as connecting with other users on social DApps. Finally, our expert evaluations may not accurately represent users' behavior in practice. Our evaluations still uncover important usability issues that carry significant security and privacy implications for users.

IV. Research Agenda

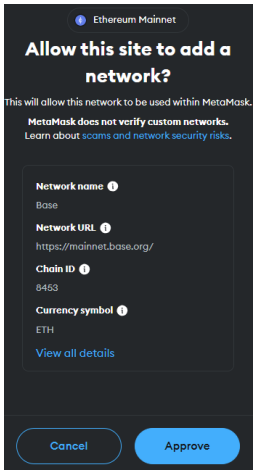
We now present the highest priority usability issues we found during our walkthroughs of 50 DApps, focusing on issues that may lead users to make dangerous errors (G5). We would direct future research efforts to consider these issues.

A. Issue 1: User interfaces, indicators, and prompts

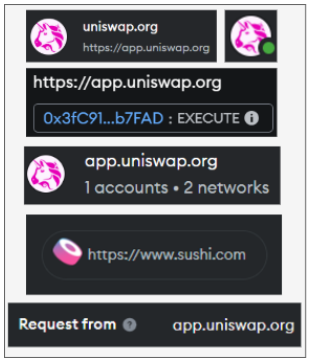
Users can have multiple DApp websites open at once, while the wallet is a singular and separate interface. We found MetaMask attempts to associate prompts with its originating DApp by displaying domain names, however it is inconsistent. In 100% of the ($n = 45$) prompts for adding a network (Fig. 2a), we found that the wallet did not link prompts to websites: *e.g.,* 'allow *this site* to add a network?' Connecting to a malicious network compromises the user's

[4]https://dappradar.com/

[5]We attempted another transaction submitting with the default ("market") gas fee limit, which was successful.

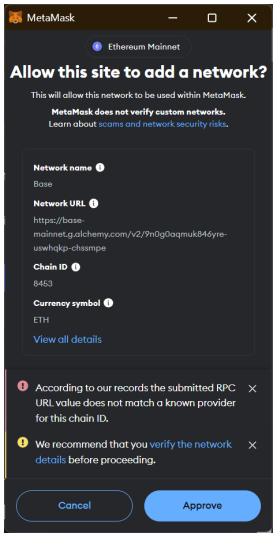


(a) No DApp indicator

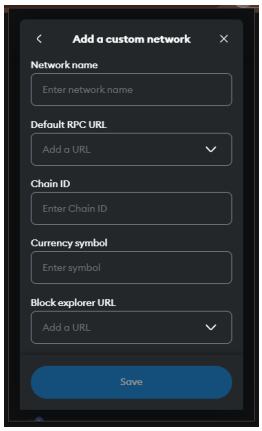


(b) Variations in DApp indicators

Fig. 2: Lack of consistent cues to link prompts to DApps.



(a) Add network prompt prioritizing simplicity over security.



(b) Add network prompt sacrificing usability for security.

Fig. 3: Challenges in adding a new network to the wallet.

privacy (links user's IP address and wallet addresses), displays information about the state of the blockchain, and can propose fraudulent transactions (timed to follow specific user actions). In other cases, the domain is shown but the visual cue varies (boxed/rounded/unboxed; domain/url/favicon; sizes/colors/locations); overall, we found six variations (shown in Fig. 2b) in how the wallet displays the domains.

Transactions can also queue, say if a user forgets to sign/cancel a transaction in MetaMask or clicks multiple times on the website. MetaMask indicates the number of current requests in the extension icon and a textual indicator in a small font size, but is easy to miss. Users, who have unknowingly queued a transaction and proceed to a new DApp where they take an action that creates a transaction, will be presented with the earlier queued transaction for signature first.

Future Work: A previous paper [26] introduces TLS-based authentication of contracts and proposes augmenting MetaMask with warnings (similar to web 2.0 browser certificates), though MetaMask has not included such proposals. We recommend that the requesting DApp's URL is in every wallet prompt in a consistent UI component (i.e., location, format). The wallet could also warn users when the requesting DApp is not in the current (in-focus) view, bring the requesting DApp's web page to in-focus view, or disable the approve button until the page is in focus to restrict inadvertent approvals.

B. Issue 2: Cross-chain switching issues

It is a common task for web3 users to switch their wallet to different blockchain networks when interacting with DApps. When adding a new network, it is the user's responsibility to evaluate its security and privacy as wallets do not verify. However, this tends to be an arbitrary process where users need to rely on ad-hoc web searches to check the network [27], [**?**]. This manual process is also extensive as it involves verifying the individual details displayed about the network including the network's name, RPC URL, chain ID and its currency.

There are three options for adding a new network on a MetaMask wallet, and each option may involve different usability and privacy and security implications:

1) Users may add a new network from a DApp site (e.g., by initiating a transaction on the relevant blockchain) which would send the wallet network information including the DApp's preferred RPC provider (as shown in Fig. 3a). In this case, the wallet prioritizes simplicity and prompts the user to add the network specified by the DApp. This prompt does not allow the user to select a different (e.g., more privacy-friendly) RPC, or even indicate the possibility of changing providers. Thus, users may consent to using the displayed network though they may not be fully informed or even aware of more privacy-friendly choices.
2) Second, for a small subset of (popular) networks [**?**], users can add the network automatically from the MetaMask interface using suggested providers (e.g., a related entity—see Sect. II-C). Wallets may be able to inform users about potential security and privacy issues with specific network providers, however, this may be possible only for a limited number of networks.
3) Third, users can add a network on their wallet by manually configuring the network such as their preferred RPC (Fig. 3b). Although this option offers the most control to users, it may not be straightforward to identify legitimate network providers that are trustworthy.

These issues complicate the process of configuring networks by requiring users to perform multiple out-of-band checks (i.e., breaks the user's workflow for the task by involving external resources and ad-hoc web searches). MetaMask prompts include warnings (as in Fig. 3a) when the network information (e.g., name, RPC URL, or currency) provided by the DApp does not match its own records; 62% of the 45 prompts

we reviewed included at least one warning about networks. However, users may become desensitized to security warnings especially when they are frequently linked to false alarms [28].

Future Work: When adding a network, users should be made aware of alternative providers who may offer better security and privacy. To this end, when adding networks via DApps, wallets can simply display an option to change the provider before adding to the wallet. It is important for users to be informed about available choices before they make a decision since adding a network to the wallet immediately exposes personal information such as user's IP address and wallet addresses (which can then be linked to past transactions, compromising privacy). To further support informed user decisions, DApps and wallets could list more than one provider for the user to choose from, and provide information about the benefits of each network in terms of transaction speed, gas fees, security and privacy properties; existing resources such as ChainList[6] already provide information about alterantive RPC servers and their privacy and speed.

C. Issue 3: Unpredictable function behaviour

When prompting for a transaction approval, MetaMask includes predicted changes (Fig. 4) to the user's balances (i.e., estimated amount "sent" and amount "received") for recognized tokens and blockchains [29]. Among 40 transaction prompts, we found 25 prompts (63%) with predictions on received tokens. Such predictions may mislead users into falsely assuming that the transaction would actually result in receiving tokens whereas the wallet does not perform any security checks, i.e., misplacing trust on the contract despite the lack of validation or security checks. Though the wallet warns (in a small icon) that the predictions are not guaranteed, users may not fully comprehend the risks or may miss the warning completely.

Other approaches have been proposed to extract information about contracts. Solidity, the primary language for contracts, provides developers the ability to write special user-facing comments about their contract code [30]. However, most of the contracts in the wild do not include such comments [7]. Automated generation of these comments could help fill this gap [7] but such comments may not provide accurate descriptions of contracts and may lead some users into a false sense of security about contract behavior. Another line of research focuses on security tools (e.g., [31], [32]) to identify vulnerable contracts, however informing users about these issues (e.g., in end-user interfaces) remains an open challenge.

Future Work: Wallets should use a standard interface design to inform users about contract risks. When interfaces includes predictions about balance changes, it should clearly warn users about the lack of validation about the contract to prevent false trust assumptions. All warnings should be displayed using a consistent and prominent format. Future research can determine the extent to which malicious behavior can be predicted through automated analysis (or DApps could default to untrusted until certified).

[6]https://chainlist.org/?chain=1

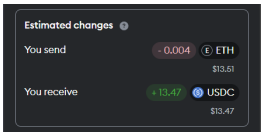


Fig. 4: Transaction predictions by wallet.

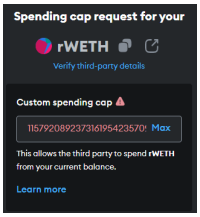


Fig. 5: DApp request for unlimited approval.

D. Issue 4: Concerns with revocation

The final issue has been explored in the literature by Wang *et al* [33] but we include the issue for completeness. Tokens deployed on Ethereum follow standard interfaces, such as ERC20, meaning wallet software can interoperate even without knowing anything specific about the token. The ERC20 standard requires an 'approve' function. Instead of Alice sending 10 tokens to Bob, she can approve Bob to take 10 tokens from her at any time until she removes the approval. Many DApps move tokens through approvals rather than transfers.

Prioritizing simplicity and flexibility over security, 18 of 29 DApps (62%) in our study request *unlimited* approvals; Fig. 5 shows an example request. Similarly, Wang *et al* [33] found 60% of DApps requesting unlimited approvals. Unlimited approvals are problematic when a DApp is later compromised (or malicious to begin with) [34], [35]. Many DApps provide no option to adjust the approval amount, while some have been found to display one amount but prompt for unlimited (observed in [33] as an example of a deceptive/dark pattern [36]). While MetaMask does allow approvals to be adjusted, once set, it is up to the user to remember to un-approve.

Future Work: Attention has been given to allowing users to view, modify, and revoke past approvals, both in the MetaMask dashboard and through third-party tools (e.g., revoke.cash [37]). Because of the ERC20 standard, wallets should recognize an unlimited approval and better warn users, schedule a reminder prompt to revoke for a later time, or allow users to set global limits (with sensible default values) on allowances.

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APPENDIX

A. Selection of Core Tasks

We make the following assumptions about the user during our walkthroughs:

- Technical awareness:
  - Comfortable with web 2.0, smartphone apps, browser extensions, browsers
- Blockchain-specific awareness:
  - A wallet contains tokens (or an address that owns tokens)
  - Tokens are digital things of value that can be transacted and wallet tracks the "balance"
  - Transactions are approved by wallet
  - Approval tied to some secret value (key, seed phrases) which is "in" the wallet
  - Where the Bitcoin usability literature leaves off
- Study specific assumptions:
  - Always connect from mainnet Ethereum

Our initial list of tasks included:

- Installing and configuring MetaMask the software
  - Not part of our study, common to all web3 DApps
- Configuring MetaMask to have an address to receive tokens

  - Not part of our study, common to all web3 DApps
  - Assume user has default settings (address on L1 Ethereum with balance 0)
- Funding the wallet with ETH (for gas costs) and other tokens as necessary
  - Not part of our study, common to all web3 DApps
  - Tricky because of different networks: a future user study could explore Ethereum fragmentation into sidechains and L2s
- Visit a Web3 website and confirm site corresponds to intended website:
  - Not part of our study, common to all web3 DApps
  - Phishing studies have been conducted on web 2.0 that are relevant to this.
- Proceed to connect wallet to website with a practical mental model (G1-G3) of what connecting means, why the process is what it is (different web3 apps might use different processes), understanding and avoiding risks (G4-G5), and confirming connection is successful (G3) (via the website and via MetaMask).
  - Core task
- Configure wallet to connect to a desired blockchain network (if it is not already on this network). This network has to be supported by the DApp to perform transactions. The supported networks may be different on each DApp.
  - Core task
  - Might be subsumed by another task
- Conduct an operation on the web3 site that does not require wallet approval
  - Not a core task for our study as it does not involve the wallet by definition
- Conduct an operation of the web3 site that does require wallet approval, configure and sign the transaction, understand and avoid risks. Covers token balances, gas fees, approvals, signature, confirming transaction, etc.
  - Core task
- Revert, to the extent possible, any past interactions with the DApp. Disconnect the wallet, unapprove tokens, etc.
  - Core task

Our list of Core Tasks included the following:

T1. Proceed to connect wallet to website with a practical mental model (G1-G3) of what connecting means, why the process is what it is (different web3 apps might use different processes), understanding and avoiding risks (G4-G5), and confirming connection is successful (G3) (via the website and via MetaMask).

T2. Configure wallet to connect to a desired blockchain network (if it is not already on this network). This network has to be supported by the DApp to perform transactions. The supported networks may be different on each DApp.
  - Might be subsumed by T1 or T3.

T3. Conduct an operation of the web3 site that does require wallet approval, configure and sign the transaction, understand and avoid risks. Covers token balances, gas fees, approvals, signature, confirming transaction, etc.

T4. Revert, to the extent possible, any past interactions with the DApp. Disconnect the wallet, unapprove tokens, etc.