User Perspectives on Blockchain Technology: User-Centered Evaluation and Design Strategies for DApps

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ABSTRACT Emerging technologies have played an important role in driving major changes in human society. However, the advent of most technologies is typically initially accompanied by confusion; this is often because technology developers overlook the user perspective. This study was conducted to systematically determine the fundamental causes of problems that users encounter when they interact with blockchain technology, one of the promising emerging technologies today, and to suggest relevant design strategies. To this end, usability evaluation was conducted for the KDEX decentralized exchange application. To ensure the effective identification of the significant usability problems, heuristic evaluation with four experts and usability testing with 23 experimental participants were carried out. The results obtained show that more user-centered design is necessary to enable the widespread use of decentralized applications. Based on the experimental findings, actionable design strategies that facilitate the effective utilization of emerging technologies are suggested. The proposed strategies are expected to enable users to easily understand and navigate applications based on these technologies.

INDEX TERMS Decentralized application, decentralized exchange, heuristic evaluation, usability testing, user-centered approach

I. INTRODUCTION

The term “emerging technologies” refers to radical technologies in the early stages of development that have a high potential for application in society in the near future [1, 62, 63, 64]. These technologies have been developing at a rapid rate, and some of them have been expanding their influence on the day-to-day activities of people. For example, in just 30 years since its appearance, the World Wide Web (WWW) has completely changed human society. Several business areas have declined, and internet-based companies such as Amazon and Google have grown on a global scale. Since the release of Apple’s first iPhone in 2007, the use of smartphones has rapidly increased. Eighteen million iPhone 11 were sold just in the first quarter of 2020; today, they serve as powerful portable computers. In terms of industrial impact, emerging technologies are considered to have the potential to create new industries or transform existing ones [2, 3]. Therefore, businesses must focus on emerging technologies to retain and engage customers; indifference to emerging technologies and the changes they bring often leads to elimination from the market.

Interest in new technologies is not sufficient to lead future markets. It is also necessary to understand the novel contexts in which these technologies interact with people, in addition to the difficulties that arise from new technologies [3, 4]. Technological innovation is accompanied by new types of interactions. In other words, a new technology implies a new user experience (UX). Although exploring the applicability of technology is important, the technology can be left unused if developers do not consider UX. The success of technologies that are widely used in our daily lives occurred because there was deep consideration of the user interacting with the technical
aspects. The initial emergence of the Internet involved very little concern for users, thereby resulting in user confusion. Decades later, the Internet has been playing an increasingly important role in the world, and extensive research has been conducted on UX relating to factors such as screen layout and navigation [80]. The widespread usage of smartphones would also have been impossible without research on new experiences introduced by touch interaction, a completely new type of human–computer interaction for its time.

Indeed, emerging technologies are ahead of the general users’ ability to understand and utilize them. Technology is extremely powerful and has the ability to change the world; however, it cannot reach its full potential unless people feel the need to use it. Several researchers agree that the perspective of the user should be focused on instead of the technology itself to ensure the success of an emerging technology [65, 79]. Designing new experiences is a process that facilitates a relationship between technology and users; thus, balanced research must be conducted from both perspectives. When applying an emerging technology, developers should assign equal importance to the UX design strategy and the development method.

Blockchain was selected as one of the top five technologies of 2018 in the Gartner hype cycle of emerging technologies [6, 7]. Further, it is receiving attention as a promising technology because it is expected to solve the limitations of existing centralized networks through advantages such as anonymity and transparency. Several researchers have asserted that the significance of blockchain technology in future societies will be similar to that of the Internet itself [8, 66]. Although the technical characteristics of blockchain can introduce considerable changes to users, few studies have reviewed the new changes introduced by blockchain technology from the user perspective. This study was conducted to determine the factors that impede the success of emerging technologies from the user perspective. To this end, a user-centered approach to blockchain technology was considered. Experts on both UX and blockchain conducted a heuristic evaluation, and a group of general users participated in user testing on a decentralized exchange to identify issues that impede the use of a decentralized application (DApp). The testing results indicated the major hurdles of DApp. Based on the derived problems, a DApp design strategy is presented.

The main contributions of this paper are as follows:
1) Factors hindering the use of DApps are explored through systematic usability testing. In addition to expert evaluation, the behavior of users was observed to identify usability problems in DApps.
2) Design strategies for the successful introduction of DApps are suggested. These strategies are obtained by analyzing the problems identified based on the user perspective. The proposed strategies can be applied to other emerging technologies beyond blockchain.

The remainder of this paper is organized as follows. Section 2 gives an overview of blockchain technology, decentralized exchange, and the user-centered approach. Section 3 discusses the current status of user-centered research on blockchain technology. Section 4 outlines the method used in this study. Section 5 presents and analyzes the results of the study. Section 6 introduces and discusses the major hurdles facing the introduction of blockchain technology identified in this study. Section 7 proposes considerations for DApp designers. Finally, Section 8 concludes this paper.

II. BACKGROUND

A. BLOCKCHAIN AND ITS APPLICATIONS

Blockchain refers to a technology that stores a set of data (called a block) in a distributed environment in the form of a “chain” based on a peer-to-peer (P2P) network [9]. The advantage of a centralized network is that all transactions are centrally recorded and maintained, reducing the recording cost. However, centralized management forces the participants to rely heavily on trust in the central institution [10]. In the blockchain network, the ledger in which transaction information is recorded is distributed to all network participants rather than a central institution. When a new transaction occurs, it is recorded on a new block, which is then added to the end of the existing chain of blocks. All participants repeatedly store and maintain the ledger to reflect the new transaction. Through this process, a pure P2P network can be implemented in a stable manner.

Blockchain networks have several characteristics that differ from those of centralized networks. For example, blockchain networks do not handle the private information of a user during a transaction [11]. Through data encryption, a transaction can proceed in a manner that can identify but not characterize an individual [12]. These characteristics protect the privacy of users at a higher level compared to traditional payment methods that require personal information such as bank accounts and credit cards [13]. Further, all blockchain network participants can access all transaction data, and modifying or deleting data recorded on the blockchain have an extremely high computational cost [14]. Thus, data recorded on the blockchain has high transparency and traceability.

With its characteristics, blockchain technology can help increase the competitiveness of services. It is being actively considered in several service fields, including healthcare, transportation, food, and energy [15, 16]. In addition, it has received significant attention in the field of finance because it effectively prevents fraud (such as multiple payments) in transactions between individuals without intermediary support.
B. DECENTRALIZED EXCHANGE

The use of tokens is very important for several DApps. Tokens are issued with a special purpose, and they function like coupons in a system [15, 17]. Tokens function as monetary incentives to drive desirable user behavior in many DApps [18, 19, 20, 21, 22]. Users can gain monetary benefits by exchanging tokens obtained as rewards for contributions with cryptocurrency or fiat money through a cryptocurrency exchange. Further, at cryptocurrency exchanges, a certain type of cryptocurrency can be purchased using fiat money for use within the DApp that utilizes the cryptocurrency. Cryptocurrency exchange is essential for the expansion of DApps because it functions as a monetary intermediary between the DApp and the real world. Cryptocurrency exchanges such as BKEX, P2PB2B, and MKC are being operated actively. As of 2017, the value of cryptocurrency exchanges grew to over 25 billion dollars [23].

The majority of exchanges currently in operation are implemented on a centralized network [24, 25]. However, centralized cryptocurrency exchanges have several disadvantages. For example, transaction information is centrally managed, such as in banks, and users cannot take complete control of their cryptocurrency. The central institution can abuse its power and arbitrarily block certain users or halt transactions. Further, centrally managed data are vulnerable to external attacks [9].

As an alternative approach, blockchain has been applied to implement cryptocurrency exchanges. Currently, several decentralized exchanges such as EtherEx, Coinffeine, and KDEX are in operation. The decentralized exchange builds a P2P network such that users have complete control over their assets. By introducing blockchain to a cryptocurrency exchange, high transparency, security, and anonymity can be guaranteed [26].

C. USER-CENTERED DESIGN APPROACH AND USABILITY TESTING

The term “user-centered design” first appeared in the 1980s [72]. User-centered design refers to a design philosophy that places the needs, wants, and limitations of end users at the center of the design process of a product or service [73, 78]. User participation is essential for user-centered design; although user-centered design requires a considerable amount of time and cost, it enables efficient development by minimizing the redesign stage, thereby enhancing the developer's understanding of user behavior. Further, the problems faced by the user can be specifically defined, and the most effective solutions can be derived [74].

There are many ways users can participate in the design process. In the early stage, requirements can be derived, and desirable task sequences can be collected through interviews, focus groups, and on-site observations. In the final stage, user satisfaction or usability criteria can be quantitatively measured through usability testing and questionnaires [75]. Among user-centered design approaches, usability testing is recognized as an effective approach to derive the difficulties of end users specifically [47]. Usability is a term that can be defined as usable or useful [73], and it refers to how easily a user can perform a task using a product or service [76]. As technology has become increasingly complex, usability testing has become an essential consideration in today's product and service development to minimize development costs and attract users effectively [77, 79].

III. BLOCKCHAIN TECHNOLOGY AND THE USER-CENTERED APPROACH

Blockchain technology is accepted as a promising emerging technology in both academia and industry. It is expected to introduce a revolution similar to the emergence of the Internet [16, 27]. Although public awareness of blockchain technology has increased very rapidly in the past few years, the widespread application of blockchain has not been achieved yet [28, 29]. In fact, among about 86,000 promoted blockchain projects, only 8% have survived [30, 31].

Several studies have attempted to identify the hurdles in the application of blockchain technology. The lack of standardization, the disruption of development caused by regulations, and problems related to users' understanding and awareness of blockchain technology have been noted as major barriers [32]. Among these, many researchers have pointed out that developers’ misunderstanding of DApp users is the foremost problem [15]. Because blockchain technology remains an unfamiliar concept for the majority of users, it is difficult to grasp the intrinsic value of blockchain technology, and a high entry barrier is formed. As user-related issues have become increasingly important in recent times, experts have emphasized the urgent need to improve the user perception and experience related to blockchain technology [4, 29]. In particular, to expand the use of blockchain technology, it is considered important to create an environment that is accessible to users that are not interested in cryptocurrency or blockchain technology but are interested in using DApps [33]. However, only a few studies have attempted to understand DApp users. Thus, several currently operating DApps have fundamental problems because of lack of understanding of its users.

A. USER-CENTERED APPROACH TO BLOCKCHAIN TECHNOLOGY

Blockchain has great value; however, its adoption is slow compared to its potential benefits [26]. A lack of understanding of users is emphasized as the primary cause of this phenomenon. To solve this problem, efforts are being invested in understanding blockchain technology from the perspective of the user, which is called a user-centered approach. Table I summarizes the results of a literature survey for a user-centered approach to blockchain
technology. Early research focused on investigating the perception of cryptocurrencies rather than DApps. Several studies identified motivations for using Bitcoin, which is one of the most popular cryptocurrencies, through interviews [34, 35, 36]. With the active development of DApps, research has gradually increased. Ma and Pan [4] and Meeuw et al. [37] suggested measures for improvement by collecting user's opinions on data structures and page layouts. Glomann et al. [29] interviewed experts to ascertain the UX issues faced in blockchain applications.

### TABLE I

Existing studies with a user-centered approach to blockchain technology

| Study            | Purpose                                               | Method          |
|------------------|-------------------------------------------------------|-----------------|
| Khairuddin et al. [34] | Exploring the motivations for using Bitcoin.           | User interview  |
| Gao et al. [35]  | Investigating the motivation for using and requiring Bitcoin. | User interview  |
| Sas and Khairuddin [36] | Exploring the motivation for using Bitcoin from a trust perspective. | User interview  |
| Meeuw et al. [37] | Proposing a data structure for energy transaction using blockchain. | User interview  |
| Ma and Pan [4]   | Investigating effective page layouts in blockchain-based transactions. | Eye tracker, user interview |
| Glomann et al. [29] | Exploring UX issues in blockchain applications. | Expert interview |

Although several blockchain studies have been conducted, the majority of them were aimed at applying technology or facilitating system development. Few studies have explored the lack of widespread acceptance of blockchain technology from the user perspective. Whereas some recent studies have considered a user-centered approach to DApps, the majority of them have been performed in very limited contexts with specific purposes, including the improvement of structures or layouts. Glomann et al. [29] examined the overall UX of DApps through expert interviews; however, experts already have a strong understanding of the technology, and thus, they do not appropriately represent general users. Therefore, to overcome the limitations of existing studies, it is necessary to identify concrete problems in DApps and deeply analyze these problems through the cooperation of experts and general users.

### B. USABILITY OF DAPPS

Previous studies attempted to collect users’ experiences and opinions on blockchain technologies by conducting interviews. Gathering experience in an uncontrolled scenario helps to gain a broader understanding of a user's experience with the technology; however, it is insufficient to elicit specific problems affecting usability. Because poor usability becomes the main factor that impedes the use of emerging technologies, improving usability should be dealt with very importantly among the various other attempts to achieve a user-centered approach [38]. In this context, usability testing can be an effective approach to gain insight into the user perspective [39]. In particular, experiments with real users play a very critical role in understanding the technology from the perspective of the user [40]. Nevertheless, few studies have explored the usability of DApps systematically. Most of the research on decentralized exchanges is focused not on the usability to users [41] but on technical implementations [9, 42, 43] or legal regulations [44]. Some studies mention that usability remains a key research topic for the success of blockchain technology [67, 68, 69]. They emphasize that most blockchain usability research provide solutions for developers and not for end users. For example, Decker and Wattenhofer [70] proposed auditing software to improve the usefulness of bitcoin exchanges, and Di Battista et al. [71] proposed a system for visually analyzing bitcoin flow on the blockchain. For DApps to be operated actively, it is necessary to identify and solve their problems systematically by evaluating usability from the user perspective.

This study aimed to understand UX with a decentralized exchange—a type of DApp—to identify the usability problems hindering the use of DApps. Decentralized exchanges facilitate the exchange of the cryptocurrencies utilized by most DApps. In addition, because the cryptocurrency transaction process is similar to the cryptocurrency wallet functions used by most DApps and transactions without intermediaries, decentralized exchanges are expected to have similar user experiences as other DApps. Therefore, it is one of the DApps that should be primarily researched.

### IV. METHOD

In this study, a usability evaluation was conducted on the KDEX mobile application, a decentralized exchange (Fig. 1), which was launched in Korea in 2018. In most decentralized exchanges, real-time trading is difficult because of the time delay in recording transactions on the blockchain. To overcome this limitation, KDEX applies a “ready-pending” system. Ready-pending supports the next transaction by admitting the pending transaction that has been processed but has not yet been recorded on the blockchain as completed.
The usability problems of KDEX were identified through two methods: heuristic evaluation and user testing (Fig. 2). To conduct the two evaluations effectively, a preliminary survey was conducted before the heuristic evaluation, and a pilot test was conducted before user testing. In the preliminary survey, the main tasks performed in cryptocurrency exchanges were listed. Based on the derived tasks, experts performed a heuristic evaluation to understand the function and task procedure of the application. Subsequently, the experimental design was modified to conduct user testing in the pilot test efficiently. Finally, user testing was conducted for users with no experience in using cryptocurrency exchanges. The identified usability problems were classified and analyzed based on the tasks.

A. HEURISTIC EVALUATION

Heuristic evaluation is a usability engineering approach proposed by Nielsen and Molich [45]. It is used to identify usability problems in the user interfaces of web or mobile applications. Usability experts conduct the evaluation based on predetermined evaluation criteria [46, 47]. There is a gap between the expert and the perspective of the actual user, and the results are highly dependent on the skill level of the experts. However, it is useful for evaluating systems because it is easy and quick to apply, and it incurs a reasonable cost [45, 47]. The ten heuristic evaluation criteria used in this study were adopted from [48]. They are visibility of system status; match between the system and the real world; user control and freedom; consistency and standards; error prevention; recognition rather than recall; flexibility and efficiency of use; aesthetically pleasing and minimalist design; help users to recognize, diagnose, and recover from errors; and help and documentation.

The number of experts participating in a heuristic evaluation has a significant effect on the results. One expert is expected to identify about 35% of the problems [49]. The larger the number of evaluators, the greater is the number of problems that can be identified. The most cost-effective number of experts is between three and five. It is expected that 60–75% of usability problems can be identified via evaluation using only three to five experts [49].

![Figure 1. Screenshots showing the main, transaction history, and cryptocurrency wallet screens of KDEX.](image)

![Figure 2. Process of the study.](image)

Four experts of both UX and blockchain technology performed a heuristic evaluation. The average experience of the evaluators was five years. The experts were proficient in UX and HCI, and they had sufficient knowledge of the technical principles and applications of blockchain technology. Prior to the heuristic evaluation, a preliminary survey was conducted to derive the main functions of cryptocurrency exchanges. As a result, six tasks were derived (Table II). The heuristic evaluation was conducted over a five-day period; at this time, each expert performed the six tasks in KDEX and recorded the problems identified. Following the completion of the evaluation, all evaluators checked and shared the identified usability problems.

| Task No. | Task | Explanation |
|---|---|---|
| 1 | Sign up and login | Sign up as a member and log in to the KDEX mobile application |
| 2 | User authentication | Complete the user authentication process for transactions and deposit |
| 3 | Deposit | Complete the user authentication process for transactions and deposit a certain amount of cash into the application |
| 4 | Check the chart | Check the cryptocurrency chart to view trends in trading amounts, volumes, etc. |
| 5 | Trade | Buy and sell cryptocurrency |
| 6 | Check assets | Check the type and amount of assets |

B. USER TESTING

Although a heuristic evaluation has the advantages of being fast and highly affordable, it derives several minor problems that do not significantly affect user performance, which are called false positives [47, 49, 51]. Therefore, in this study, user testing was conducted to identify usability problems that have a serious effect on user performance. Although user testing requires a considerable amount of time and cost, it can identify problems that substantially affect performance and measure user satisfaction when interacting with an application. From previous studies, it is known that usability problems are efficiently identified by combining heuristic evaluation and user testing [50].

A total of 23 users (14 male, 9 female) participated in the user testing. All users had no prior experience in using cryptocurrency exchanges. Their average age was 24.9 years (SD 4 years; minimum = 20 years and maximum = 35
years), and all participants were familiar with using mobile applications without physical or cognitive difficulties.

Before the testing, a training session was held to ensure that each participant fully understood the purpose and process of the experiment. Users were notified that KDEX was a blockchain-based exchange; however, they were not informed how blockchain technology is specifically applied. It was observed from the pilot test that the participants who did not have experience with certain tasks such as checking the chart (task 4) and trading (task 5) focused on learning to perform those tasks rather than on finding usability problems. To prevent this, a stock exchange application was used to train them in tasks 4 and 5. In addition, in the cases of tasks 4 and 5, differences may occur between the participants in the experiment depending on the type of cryptocurrency being used. To minimize these differences, participants were asked to perform tasks using only Ethereum, which is considered an appropriate cryptocurrency for experiments because it is trading at a reasonable price of around $400, and it is one of the most actively traded cryptocurrencies. Subsequently, participants performed the six tasks as in the heuristic evaluation (Table II).

The time taken to complete each task was measured, and the success status was recorded. To determine the task completion time, participants were asked to ring the bell when they began each task and again when they considered it to be complete, regardless of the actual success or failure of the task. Although the entire process was videotaped with their consent, the time when the experimenter and the user determined that the task was complete may differ. By ringing the bell, the experimenter could pinpoint when the user actually believed that the task was completed. Upon finishing each task, a usability score signifying the convenience of using DApp while performing the task was determined from an 11-point Likert scale (0: very inconvenient, 10: very convenient).

As a long experimental time could affect the concentration of the participants, the experiment time allotted for each task needed to be limited. A pilot test showed that when the task was performed without difficulty, the task time did not exceed 3 min for all tasks. Further, the participants in the pilot test could abandon the task if they did not know how to perform the task. The abandoning time did not exceed 10 min in any case. Therefore, in this study, a task that required more than 10 min was considered a failure. During the experiments, participants were allowed to rest and resume when they wanted if they felt tired.

There were two types of task failures. The first was a task that was not completed within 10 min (Type A failure). The second was a task that was not properly completed but was marked as complete by the participants (Type B failure). At the end of each task, participants were interviewed on the usability problems they encountered, regardless of the task success. Because the completion of the previous task affects the ability to proceed to the next task, the remaining processes of the failed task were completed by the experimenter. After completing each task, the participants were interviewed to ascertain what kind of usability difficulties they had encountered, regardless of success or failure.

V. RESULTS

Table III lists the number of participants who failed and the success rate for each task. A total of seven participants succeeded in all tasks, which accounts for only 30% of the total. Among the 16 participants who failed more than one task, 10 failed in one task, five failed in two, and one failed in three. All participants successfully completed tasks 1 and 6. The task with the lowest success rate was task 3, with more than half the participants failing. In terms of failure type, there were 17 participants for Type A failure and six for Type B failure, thereby indicating a significantly higher rate of Type A failure.

Fig. 3 shows the average task completion time for a successful case and the average usability score for all participants. Task 2 required the most task completion time, whereas task 6 required the least time for successful cases. In task 3, seven participants did not complete the task within 10 mins, whereas 11 successful participants completed it in approximately 4 min. The average usability score was highest for task 1, and lowest for task 2.

Table IV lists the results of classifying the usability problems by task type. A total of 25 problems were found...
from the heuristic evaluation, and 13 problems were found from user testing. Among them, 10 problems were identified in both the heuristic evaluation and the user testing. In addition to the 10 overlapping problems, 15 out of the 28 problems were found only in the heuristic evaluation. Those included minor problems such as the intuitiveness of the icon and the color of the letters. Three problems derived from only the user testing were related to task 3.

| TASK | Heuristic | Both | User testing |
|------|-----------|------|--------------|
| Task 1 | Color of the sign-up button is similar to the background | · Explanation and design during the deposit process is very confusing | · The user cannot find the “deposit” button |
| Task 2 | Color of some pictures that have no function changes when the user touches them | · Insufficient guidance for authentication process | · The user misunderstands the deposit request as deposit completion |
| Task 3 | Pop-up notification messages have a limited length, which makes it impossible for the user to identify the scenario | · Even if the user can understand notifications by entering the notification menu, the notification indicator does not disappear. It only disappears when the user touches the “all notifications” list | · No information is provided about the time gap between deposit and remittance |
| Task 4 | · There is no way to access the chart screen except from the transaction screen | · When the sort button changes the item order, it does not indicate which criterion is selected | |
| Task 5 | · Buttons to change the chart options are not intuitive | · No descriptions are provided for charts or terms | |
| Task 6 | · Icons without functions are presented in the chart setting and transaction history menu | | |

TABLE IV
Derived usability problems.
VI. MAJOR HURDLES TO BLOCKCHAIN TECHNOLOGY

INTRODUCTION

Introducing blockchain technology to a cryptocurrency exchange caused a considerable number of problems. Three types of problems were identified in this study: the cryptocurrency wallet requirement, time gap between the occurrence and recording of transactions, and transaction fees.

A. CRYPTOocurrency WALLET REQUIREMENT

In task 5, several participants failed because they did not know that the cryptocurrency wallet must be created before progressing to any transaction. To understand the problems related to the cryptocurrency wallet, it is necessary to know how to use cryptocurrency wallets. A cryptocurrency wallet is a virtual object that refers to the digital credentials of the currency holdings [50]. Unlike wallets used in everyday life, which actually store fiat money, identification cards, etc., cryptocurrency wallets serve to store and manage private keys for signing transaction data recorded on the blockchain. Separate cryptocurrency wallets are required for each cryptocurrency type; only Bitcoin can be stored in the Bitcoin wallet, only Ethereum can be stored in the Ethereum wallet, and so on. To hold or trade a specific type of cryptocurrency, a wallet must first be created for that cryptocurrency. Because the process of creating a wallet before a transaction is unfamiliar to many users, relevant information should be provided. Most DApps provide a cryptocurrency wallet because they utilize cryptocurrency and tokens. Therefore, improving the usability of cryptocurrency wallets is essential to ensure excellent UX in DApps.

B. TIME GAP BETWEEN OCCURRENCE AND RECORDING OF TRANSACTIONS

The second problem is caused by the time gap between the occurrence of a transaction and the recording of the transaction in a blockchain. In KDEX, all transactions are recorded in the blockchain; however, the problem is that the occurrence time and recording time of transactions differ [38]. To prevent double-spending, transactions remain in the waiting state without transmitting cryptocurrency until the next block is created. The time between transaction occurrence and confirmation depends on the creation time of the block and the number of transactions waiting to be recorded. This time gap is significantly longer than that of existing financial transactions that users normally encounter in a centralized system, such as in a bank [26]. In the case of Bitcoin, it takes an average of 10 min to create a new block [12]. In other words, when using the Bitcoin blockchain, it takes 10 min for a transaction to be recorded. Some networks utilize a transaction-priority mechanism to provide an option to reduce recording time by paying higher fees [19, 53, 54].

As a result of the interview for task 3, it was found that the participants misunderstood the deposit process because they did not receive information about the time gap after depositing money in the cryptocurrency wallet. They assumed that they had made a mistake in the remittance process or that there was an error in the system during the time the transaction was reflected in the cryptocurrency wallet. In task 5, there was a problem of doubly generated histories for one transaction. This was not encountered during the user testing owing to insufficient experiment time. KDEX provides a “ready-pending” function to overcome inconsistent and long waiting periods until the completion of a transaction. To enable the next transaction to occur immediately after the previous one, it assumes the transaction is completed before it is recorded on the blockchain. Therefore, in the transaction history, there are two records of one transaction: first, when the transaction occurs, and second, when it is recorded on the blockchain. It takes up to several minutes between the two events. Because users cannot receive guidance about the ready-pending function anywhere during the task, they may believe this to be a double transaction.

C. TRANSACTION FEES

There was a problem related to the transaction fee, which was found only in the heuristic evaluation. In KDEX, the transaction fee varies depending on the payment method, even if a user purchases the same type of cryptocurrency (Fig. 4). There are two types of fees: the platform fee and the blockchain network fee. The platform fee is the fee for using the KDEX platform, and the blockchain network fee is that for recording a transaction on the blockchain. When a buyer performs a transaction that pays in fiat money, both the buyer and the seller must pay a platform fee equal to 0.1% of the transaction amount. At this time, the seller must additionally pay the blockchain network fee in fiat money. If the buyer purchases another cryptocurrency with a specific cryptocurrency that they own, a platform fee equal to 0.2% of the transaction amount and a blockchain network fee in fiat money are charged to both the buyer and the seller. This policy on fees is not only difficult to understand, but the criteria for setting the fee amount and the means of payment are ambiguous. Users who are unfamiliar with blockchain technology might not understand the blockchain network fees, which do not exist in a centralized system. The results of this study show that the DApp design, which is considered reasonable by technology developers, can be severely problematic for users. This indicates that DApp providers are not sufficiently considering the changes that blockchain introduces. It is expected that usability problems caused by introducing blockchain can be solved by accurately accounting for changes and systematically analyzing their effects on task performance.

VII. DESIGN CONSIDERATIONS FOR DAPPS

The majority of DApps developers focus on functionality, maintenance, and stability [29]. However, the results of this study and several recent studies suggest that developers need to invest more effort in understanding UX.
Hen performing tasks, the “Receive” ts of the r its value to its al model. Some participants ate that have a mental model for similar systems, it is recommended were caus ed by an inac curate mental model. As most users have a mental model for using bank accounts, may be confused when they first encounter these terms. Numerous usability problems in tasks 3 and 5, related to cryptocurrency wallets and transaction fees, respectively, were caused by an inaccurate mental model. As most users have a mental model for similar systems, it is recommended that a mental model that users already have or are familiar with be implemented. By utilizing an existing mental model, the effort invested by the user to build a new mental model can be minimized, which can contribute to lowering the entry barrier to blockchain technology.

### A. ADOPT MENTAL MODEL FROM SIMILAR SYSTEMS

A mental model is an intuitive understanding of a system’s functionality in terms of its internal structure and processes [55, 56, 57]. It helps users interpret the actions of the system and predict the outcome [56, 58]. Difficulty in forming a suitable mental model for a system is a primary cause of usability problems [59]. Therefore, it is necessary to establish an appropriate mental model to eliminate difficulties in the use of DApps. When performing tasks, the majority of participants assumed that KDEX would have the structure and operation method similar to bank applications. However, because KDEX was designed to work differently from bank applications, users needed to build a new mental model. Some participants stated that this was not difficult once they determined how it works; however, it is difficult to understand initially.

The cryptocurrency exchange usage procedure is similar to that of some existing systems; the cryptocurrency trading function is similar to that of a stock exchange. Further, a cryptocurrency wallet is similar to a bank account in that it supports the management and transfer of cryptocurrencies (Fig. 5). However, KDEX does not use a mental model similar to any existing system. For example, a wallet address that acts similar to a bank account number is long and has no rules, which makes it difficult for general users to remember. In addition, most cryptocurrency wallets provide functions such as “receive” and “send.” “Receive” simply means sharing the wallet address. General users, who have a mental model for using bank accounts, may be confused when they first encounter these terms. Numerous usability problems in tasks 3 and 5, related to cryptocurrency wallets and transaction fees, respectively, were caused by an inaccurate mental model. As most users have a mental model for similar systems, it is recommended that a mental model that users already have or are familiar

### B. DELIVER THE VALUE OF DAPPS

DApp developers attempt to add several advantages when introducing a blockchain into the system. KDEX can almost completely block external attacks, which are the greatest threat to existing centralized exchanges. Unlike centralized exchanges, which require the exchange to fiat money and withdrawal to a bank account to hold the traded cryptocurrency, cryptocurrency possession is immediately granted to the buyer in KDEX. The ownership of the cryptocurrency is confirmed immediately after the transaction is recorded on the blockchain. Further, KDEX has high security and transparency as all transactions are recorded on the blockchain. However, none of the participants commented on these advantages, which indicates that the DApp failed to deliver its value to its users.

For a DApp to survive in the market, it is important to effectively deliver the value of the application to users [26, 29]. The more attractive the technology, the more likely it is that technology experts will focus on the benefits of the technology and disregard the users’ actual acceptance of the value of the technology [59]. Blockchain technology remains an unfamiliar concept to the majority of users, thereby making it difficult for users to grasp its intrinsic value. Rather than explaining the technical value of blockchain technology to general users, it is necessary to design it such that users can intuitively find advantages while using the DApp. It is possible to deliver the value of a DApp effectively by ensuring good usability and interaction experiences [61]. Poor interaction experiences lead to users utilizing only the features they can accept, which deprives them of the opportunity to experience the value of emerging technology [60]. Therefore, developers should contemplate approaches to provide good usability when introducing blockchain applications. With excellent usability, users can easily grasp the value of DApps.

### VIII. CONCLUSION

This study conducted usability testing on a decentralized exchange to investigate the cause of blockchain technology not being accepted by users despite its value. In addition to the general usability problems that appear in mobile
applications, the major problems that appeared when introducing blockchain to cryptocurrency exchanges were identified. Many researchers emphasize the need for a user-centered approach whenever new technologies emerge; however, the results of this study show that this is not being applied in the industry. Based on our findings, two primary strategies are suggested for developers to ensure the acceptance of blockchain technology: adopting a mental model from similar systems, and effectively delivering the value of the technology through good usability.

This study conducted an experiment with users in their 20–30s, who are very familiar with using mobile applications. In addition, because the experiment was conducted only on decentralized exchanges—one of the DApps in the financial field—it is difficult to reflect the characteristics that can appear in various fields where blockchain is actively used accurately, such as in SNS and medical service. Nevertheless, this study is significant in that it proposes a systematic approach for the successful introduction of emerging technologies.

Blockchain technology can be used for a variety of applications in a wide range of fields. More meaningful insights can be obtained by comprehensively analyzing user-centered studies on DApps in various fields as well as on other emerging technologies.

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