Lernmethoden zur Vermittlung von Blockchain Grundlagen an Nicht-ExpertInnen im Energiehandelskontext

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Diplom-Ingenieurin

im Rahmen des Studiums

Media and Human-Centered Computing

eingereicht von

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Wien, 20. Februar 2020

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Faculty of Informatics

Learning Methods for Non-Experts to Understand the Fundamentals of Blockchain in an Energy Trading Context

DIPLOMA THESIS

submitted in partial fulfillment of the requirements for the degree of

Diplom-Ingenieurin

in

Media and Human-Centered Computing

by

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Vienna, 20th February, 2020

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Marie Valerie Riegler

Danksagung

Herzlich danken möchte ich Simone Kriglstein und Margit Pohl, denen ich vor allem für ihre Geduld und Mühen bei der Betreuung meiner Diplomarbeit danke. Durch Ihre kontinuierlich hilfreichen Anregungen und konstruktive Kritik sind das Thema und die Umsetzung zustande gekommen.

Ebenfalls möchte ich den Forschungsbereichen Human Computer Interaction und Multidisciplinary Design & User Research am ehemaligen Institut für Gestaltungs- und Wirkungsforschung für die zahlreichen inspirierenden und lehrreichen Lehrveranstaltungen und die dortige sehr persönliche Betreuung danken, an welchen ich vor allem im Laufe meines Masterstudiums teilnehmen konnte.

Meinen KollegInnen im Zuge meines Praktikums am Center for Technology Experience am Austrian Institute of Technology möchte ich für die kollegiale Unterstützung, Feedback und gemeinsame Mittagessen danken.

Weiters möchte ich der Research Group Cooperative Systems der Universität Wien danken, welche ihren Untersuchungsraum für meine Studie bereitgestellt und mir ermöglicht haben, StudienteilnehmerInnen über eine ihrer Lehrveranstaltungen zu rekrutieren.

Ein besonderer Dank gilt meinen beiden Brüdern Michael und Christian, welche ebenfalls Informatiker sind und mich vor allem in den ersten Semestern meines Studiums tatkräftig unterstützt haben.

Auch meinen Freunden und meiner Familie danke ich für den emotionalen Rückhalt den sie mir durch lange Gespräche, Tränenlachen und diversen gemeinsamen Unternehmungen boten.

Insbesondere möchte ich abschließend meinen Eltern danken, die mich sowohl finanziell als auch mit gutem Essen und einem stets offenen Ohr unterstützt haben.

Acknowledgements

I would like to give thanks to Simone Kriglstein and Margit Pohl, to whom I would like to express my gratitude for their patience and efforts in overseeing my diploma thesis. Without their guidance and continuous constructive feedback this work would not have materialized.

Also I would like to thank the Research Divisions Human Computer Interaction and Multidisciplinary Design & User Research of the former Institute of Design & Assessment of Technology for their numerous inspiring and educational courses in which I could participate during my masters studies, and foremost the personal supervision and support they provided.

My colleagues during my internship at the Center for Technology Experience at the Austrian Institute of Technology I would like to thank for their friendly support, feedback and joint lunches.

Furthermore I thank the Research Group Cooperative Systems at University of Vienna who provided their lab room for my study and enabled me to recruit study participants through one of their courses.

A special thanks goes to my two brothers, Michael and Christian, who are also computer scientists and have supported me a great deal, especially in the first semesters of my studies.

I just as much thank my friends and my family for the emotional support they offered me by long conversations, laughing tears and various spare time activities.

Finally, I am deeply grateful to my parents who have supported me not only financially but also with delicious food and an always open ear and plenty encouraging advice.

Kurzfassung

Da Blockchain zu einer aufstrebenden Technologie wird und in immer mehr Anwendungen für Haushalte eingesetzt wird, beispielsweise im Peer-to-Peer Energiehandel, können Nicht-ExpertInnen nun aktiv an Blockchain-Anwendungen teilnehmen. Daher wird es mehr und mehr relevant Nicht-ExpertInnen durch entsprechenden Informationszugang einen informierten und bewussten Umgang mit der Technologie zu ermöglichen um sich sowohl der Vorteile als auch potentieller Nachteile und insbesondere des Umgangs mit ihren Daten bewusst zu werden. In dieser Arbeit wurden drei digitale Prototypen evaluiert, die die Grundlagen der Blockchain-Technologie auf eine für Nicht-ExpertInnen zugängliche Art und Sprache erklären. Die Inhalte wurden aus der Literatur, einem Workshop mit Nicht-ExpertInnen und Experteninterviews zusammengestellt, aus denen hervorging, dass insbesondere der Umgang mit Daten, die Hauptmerkmale und Anwendungen adressiert werden sollten. Basierend auf diesen Erkenntnissen wurden die drei Prototypen entworfen und implementiert. Diese sind ein animiertes Video mit Voice-Over, ein Smartphone Spiel und eine Website. Eine NutzerInnen Studie mit 30 TeilnehmerInnen, in welcher Pre- und Post-Tests und semi-strukturierte Interviews angewandt wurden, wurde durchgeführt um die drei Prototypen zu vergleichen. Somit sind sowohl quantitative als auch qualitative Daten in die Beantwortung der drei Forschungsfragen eingeflossen: welche Methode den höchsten Lerneffekt hat (RQ1), ob sich das erhöhte Wissen auf das subjektive Komfortniveau auswirkt (RQ2) und welches Abstraktionsniveau für Nicht-ExpertInnen geeignet ist (RQ3). Die Ergebnisse der Studie zeigten, dass sich die Prototypen in ihrem Lerneffekt auf die TeilnehmerInnen nicht signifikant unterschieden. Jedoch haben sie unterschiedliche Anwendungsbereiche, da sie unterschiedliche Lerneigenschaften zeigten. Das subjektive Komfortniveau war höher und der allgemeine Eindruck von Blockchain war positiver nach dem Lernen mit den Prototypen. Schließlich wurde festgestellt, dass die Abstraktionsebene am effektivsten ist, wenn nur wenige Details enthalten sind oder diese auch vollständig erklärt sind. Visualisierungen, die sich nur auf einen Aspekt konzentrierten und den Rest abstrahierten, wurden von den TeilnehmerInnen der Studie besser in Erinnerung behalten und besser verstanden. Diese Erkenntnisse können für zukünftige Anwendungen verwendet werden, bei denen das Ziel ist, Nicht-ExpertInnen über die Blockchain-Technologie zu informieren. Möglicherweise könnten sie sich jedoch auch auf andere Lernbereiche übertragen lassen.

Abstract

With blockchain becoming an emergent technology and being used in more applications for households such as in peer-to-peer energy trading, non-experts can actively participate in blockchain applications. Hence informing non-experts on blockchain characteristics so that they are aware of its benefits but also its potential disadvantages and especially the handling of data becomes a field of interest. This work evaluated three digital prototypes that explain the basics of blockchain technology in an accessible way and language for non-experts. The contents were established from literature, a workshop with non-experts and expert interviews revealing that especially the handling of data, the main characteristics and applications should be addressed. Based on these findings, the three prototypes which are an animated video with voice-over, a mobile learning game for smartphones and a website were designed and implemented. A user study with 30 participants using pre- and post-tests and a semi-structured interview at the end and thereby using both quantitative and qualitative methods was conducted to address the three research questions of which method has the highest learning effect (RQ1), whether the increased knowledge has an effect on the subjective level of comfort (RQ2) and what level of abstraction is appropriate for non-experts (RQ3). The results of the user study showed that the prototypes didn't significantly differ in their learning effect on the participants however do have different fields of application as they showed different learning properties. The subjective level of comfort was increased and general impression of blockchain was better after learning about them through the prototypes. Finally, the level of abstraction was found to be most effective when not including many details or otherwise fully explaining what is mentioned. Visualizations that focussed on only one aspect and abstracted the rest were remembered and understood better by participants of the study. These findings can be used for future applications where the intention is to inform non-experts on blockchain technology, however they may also extend to other technological areas.

Contents

CHAPTER 1

Introduction

Blockchain as an emergent technology is receiving increased attention for business opportunities and research as well as by media and people due to its application in the popular digital currency Bitcoin. However the technology receives mixed reactions to extreme ends. While on one extreme end people believe that blockchain will remarkably disrupt various network systems and reshape the future, the other end is more skeptical and believe that the disadvantages will predominate and cause the technology as a whole to fail. In between are those who believe that blockchain has its place in the future however limited to a certain number of applications. Due to the extreme difference in opinions, information material and media coverage is largely biased as well which in turn could lead to confusion and misinformed interpretations of people.

This work originated in the course of a FEMtech internship in the context of a research project called *„Peer2Peer im Quartier“*. The project deals with the development and evaluation of a peer-to-peer blockchain application for optimization of self-consumption of photovoltaic-generated energy in real operation within an urban quarter in Vienna.

1.1 Motivation

The context of energy and smart cities offer many promising opportunities for the use of blockchain technology which is where blockchains could have a place in the future. The energy sector is besides the financial sector furthest ahead in the development and research stage of blockchain applications, according to the World Energy Council [CP17]. This high interest is because blockchain could increase trading volumes and transactional speed as well as reduce waste and transportation costs as the World Energy Council [CP17] and Sun et al. [SYZ16] describe. An example for such an application is peer-to-peer trading of energy in neighborhoods. Here, the blockchain network manages and records transactions almost automatically as Basden & Cottrell [BC17] describe, allowing consumers and small energy generators (such as private photovoltaic installation owners) to monetize their assets when they don't need them at the time according to Andoni et al. [ARF+19]. Several projects are already live and/or currently being beta tested such as Enerchain [Ene], Alliander [All], Grid+ [Gri], Greenum [Gre] and more as Chitchyan & Murkin [CM18] listed.

In this way, it becomes more important to sufficiently familiarize non-experts, who are the potential users, with this new backend technology so they could participate and benefit from these new opportunities. While it is a backend technology, several researchers report on users lacking understanding of the underlying technological concepts which leads to less users feeling comfortable using it among other problems. Gao et al. [GCL16] report on an interview study about Bitcoin that many users have misconceptions on how the protocol functions and many non-users think they cannot use it because they feel they don't know enough about it. They conclude that clear guidelines on what users need to know to use the blockchain application would help acceptance. Sas & Khairuddin [SK17] report on interviews finding that perceived difficulty, insufficient awareness of tools and transparency of transactions cause users having a hard time using and trusting the blockchain technology. In a literature research and qualitative interview study with users and developers Gusak [Gus18] also confirmed that a lack of understanding is hindering the technology's adoption into mainstream. Gusak argues that users need to understand the fundamental concepts in order to understand when to trust and when to be careful with using blockchain-based technologies.

Such studies motivate this thesis to look at blockchain technologies from an Human Computer Interaction (HCI) perspective and attempt to improve user's experience by offering an easier, more understandable, informed and trustable entryway into applications using blockchain technology. Foth [Fot17] also argues for various areas of blockchains within HCI research and development, amongst them how to communicate the characteristics of blockchain transactions such as completeness, security, authenticity and ethics. He further describes it a design challenge to create applications that are accessible for all society rather than limited to people with technology affinity.

1.2 Aim of this Work

For above described motivation, this work focuses on bringing across the fundamentals of blockchains in a way that is neutral, informative and yet in simple language, understandable for the average person using the example of energy trading. Hence the aim of this thesis was to find methods to familiarize potential non-expert users with blockchain technology based on the assumption that this would increase their adoption of blockchain-based energy sharing platforms. This work yielded three prototypes of different learning methods which were chosen and developed based on findings from literature, expert interviews and a workshop with non-experts. The prototypes were evaluated in a user study providing insights on their effectiveness for engaging potential users in the understanding of the fundamental blockchain concepts and whether they positively change their perception for using the platform.

The following research questions are addressed in this thesis and guided the evaluation of the learning prototypes:

RQ1 Which methods have the *highest learning effect* for familiarizing non-expert users with blockchain technologies for peer-to-peer energy sharing and trading?

RQ2 Does this increased knowledge affect their *subjective level of comfort*?

RQ3 Which *level of abstraction* is appropriate so that non-expert users would know enough without feeling overwhelmed?

Finally, recommendations for conveying the technological concepts of blockchain technologies to familiarize users with respective applications were elaborated based on the findings from the user study.

1.3 Methodological Approach

To reach the expected results, the following methodological approach in accordance with the user-centered design process was applied. These methods are described in more detail in chapter 3 as well as in the corresponding chapters for each part.

- Literature Research

  In a literature research, information on which parts of blockchain technology users need to understand in order to use it in a sustainable and secure way were gathered. Furthermore, learning methods and their implications as well as findings from digital learning approaches were taken into consideration. Finally, previous studies on methods for increasing user's understanding for the blockchain technology were examined.

- Requirement Analysis

  Interviews with experts addressed what is necessary for non-expert users to know about the blockchain technology in order to assess which information to include in the learning material.

  A previously held blockchain workshop with non-experts informed the learning methods from the perspective of potential users. The provided data was analyzed with regards to what the non-experts already know about blockchain and in which form they would like to learn about it.

  The combination of the expert interviews and the workshop with non-experts formed the basis for the requirement analysis of the learning methods.

- Concept and Design

  After learning about the requirements for informational material on basic fundamental blockchain concepts, three methods for conveying this information were conceptualized and designed as prototypes.

- Evaluation

  The prototypes were then evaluated and compared in a user study. Using pre- and post-tests the effects on learning and level of comfort were measured as well as preferences on levels of abstraction were gathered. Semi-structured interviews at the end of the sessions formed the qualitative counterpart to the quantitative data from the pre- and post-tests.

- Analysis of Evaluation

  The collected qualitative and quantitative data of the evaluation was then analyzed with regards to the research questions.

- Recommendations

  Recommendations for familiarizing users with the blockchain technology are presented based on the results of the evaluations.

1.4 Structure of the Work

This thesis was structured based on the methodological approach described above. Following this introduction, the fundamentals of blockchain technology are described in the first part of the literature chapter 2. The second part focused on learning methods and how they can be applied to the learning prototypes for this work. It also includes findings from evaluated digital learning methods as well as two directly related works which presented ways of familiarizing non-experts with blockchain technology. In the chapter for the methodological approach, chapter 3, the used methods and how they relate to methods known from literature are described in more detail. The requirement analysis in section 4.3 consisting of the analysis of the previously held workshop with non-experts and the expert interviews formed the basis for the prototypes which are presented in chapter 5. The conceptualization and design of the prototypes is described for each of the three prototypes including the tools and procedure for development that were applied. Images are included to get a better idea of the appearance and feeling of the prototypes. These prototypes were then evaluated in a user study, which is described in chapter 6. The analysis and results of this user study are presented in chapter 7. They are divided by research question which are each addressed with both quantitative and qualitative data. A discussion about the results and their possible implications in chapter 8 and recommendations drawn from these results in chapter 9 round up this work before the conclusion in chapter 10.

CHAPTER 2

Literature

2.1 What is Blockchain?

Blockchain is a distributed database that as an emergent technology is receiving increased attention for business opportunities and research as well as by media and people. Much of this is due to its application in the prevalent digital currency Bitcoin, however is increasingly moving towards other areas of interest as well. This section gives a brief overview on the technical components of blockchain and their respective properties leading to a number of exemplary possible applications.

2.1.1 Background

In November 2008 the concept of the blockchain technology was first published anonymously in a white paper under the pseudonym Satoshi Nakamoto [N^+08]. This paper presented the technology applied on the idea of the cryptocurrency called Bitcoin. It is worth mentioning that the term blockchain is not used in the paper, it describes a "series of blocks that are cryptographically chained together" [Mat16]. Although the author did not invent new mathematical or technological concepts, the contribution was to combine existing concepts in a way that enables new properties and applications that would lay the foundation for trustable decentralized disintermediated systems [Mat16].

In essence a blockchain is a form of storing data combined with a protocol of exchange between nodes in a network. Twesige [Twe15] compared the blockchain to the internet as both being protocols for rules and regulations in networks with the internet being the protocol for information exchange and the blockchain the protocol for value exchange. Twesige further argues that the blockchain will transform the way values are exchanged the same way the internet transformed the way information is exchanged online. This view may be quite optimistic, however Nakamoto [N^+08] laid the foundation for a protocol that would allow for anyone to trust in the authenticity of data within a distributed network [Mat16]. Mind that digital signatures merely validate that a party truly intended to sign a document, solving problems around authentication and integrity. This however does not prove when the document was signed - which is however especially in the context of exchanging values essential as Di Pierro [DP17] illustrates. In this way blockchain is a system to store timestamped data within a distributed network in a way that it becomes particularly difficult for anyone to tamper with the content of the data or the timestamps [DP17]. These properties lend itself to be used in contexts of exchanging goods but however there are also a number of other applications which will be described in 2.1.4.

What makes this so interesting to research and industry is that blockchain is able to achieve this authenticity without depending on a trusted intermediary [Mat16]. In order to establish trust that data is authentic and up-to-date, digital systems have relied on some type of intermediary or trusted party. This intermediary needs to be trusted by all participants. In many cases this does not pose a problem, however this is where blockchain could fill a niche in cases where such intermediaries are expensive, no trusted authority can be established or they cannot be trusted to fulfill their task as a trustable source of truth [Mat16].

Blockchain has generated a lot of interest in researchers as well as businesses however it received mixed reactions to extreme ends. While on one extreme end people believe that blockchain will remarkably disrupt various network systems and reshape the future, the other end is more skeptical and believe that the disadvantages will predominate and cause the technology as a whole to fail. In between are those who believe that blockchain has its place in the future however limited to a certain number of applications. The energy trading context is one of the applications where blockchains could have a place in the future. Due to the extreme difference in opinions, information material and media coverage is largely biased as well which in turn could lead to confusion and misinformed interpretations of people. For these reasons this work focuses on bringing across the fundamentals of blockchains in a way that is neutral, informative and yet in simple language, understandable for the average person using the example of energy trading.

2.1.2 Blockchain Technology: A Brief Overview

As briefly mentioned in subsection 2.1.1, Nakamoto [N+08] has managed to create a system that allows for trust in a distributed network without relying on a trusted authority. This section will give a brief overview of the components that Nakamoto put together to achieve this. The comprehensive technology however is more complex and out of scope for this work. Therefore only the most important components to a degree of detail which was relevant for the examination of the learning methods for non experts are included. First, the typical characteristics will be described before guiding through the necessary steps to add new data to the blockchain ledger whereby the structure of a block, hashes and consensus mechanisms are briefly explained.

Characteristics of Blockchains

Adapted from Niranjanamurthy et al. [NNJ18], Lin & Liao [LL17] and Iansiti & Lakhani [IL17] the characteristics of blockchains can be summarized into the following seven key elements:

- Decentralized

  An essential feature of blockchain that enables it to operate without a central authority is that it operates decentralized. Data is recorded, stored, updated and verified by multiple nodes of the participant network. It is not controlled by a single party but rather constitutes a distributed database. Participants communicate data directly with each other. They act as peers, transmitting information directly from peer-to-peer.

- Transparent

  While remaining anonymous, the data is verifiable at all times by each participating device. Participants also collaboratively add new data themselves which includes a process of mutual verification. Thus the data ledger becomes transparent and trustworthy.

- Open Source

  Many blockchain systems are open and can be reviewed as well as adapted for own applications by everyone. This enables new applications as well as trust in the technology.

- Autonomy

  The consensus mechanism allows each participant node to be able to operate transactions and thereby transferring and updating data autonomously. As data is verified by a majority of the participants of the network rather than an intermediary. Data can be trusted to be valid not because there is trust in the person who last edited it but because there is trust in the community system which is handled with a consensus mechanism (see later in this section).

- Immutable

  Once the data is recorded within the blockchain network, it cannot be changed due to the cryptographic chain. The 51% attack is a way to circumvent this by gaining control of at least 51% of nodes which forms the majority which leads to the change being accepted in the whole system as Baliga explains [Bal17].

- Anonymity

  As trust in transactions is ensured by a majority through the consensus mechanism, individual nodes i.e. participants can remain anonymous. Participants are each assigned a unique identifier address that identifies them. Exchange of data is handled with these identifier addresses rather than participants' names. This allows them to stay anonymous, not having to provide proof of their identity.

- Computational Logic

  The transactions are recorded digitally in a way so they could be understood by computers. This means they can be tied to conditions and essentially be programmed, for example to be executed automatically as soon as certain conditions apply. This is called smart contracts. As Szabo [Sza97] describes, they offer a way to structure a contractual agreement without the ambiguity of natural words and furthermore allow for trust as the conditions will be executed automatically as programmed.

These characteristics are achieved through the particular technical architecture of blockchain which consists of cryptography, time stamps, consensus mechanism and decentralized storage of data.

Steps to add Data to the Ledger

The procedure of adding a transaction or any kind of other data to the blockchain can be described in five steps adapted from Miraz & Ali [MA18] and Lin & Liao [LL17].

1. Adding a transaction to the blockchain starts with a network participant triggering the transaction. The participant sends the new data of the desired transaction to the network. Such transactions depend on the application, in case of Bitcoin this would be a money transfer.

2. The transaction is then to be approved as valid by the other participants who use a specific algorithm depending on the corresponding application.

3. Subsequently the transaction is stored into a new block together with a the cryptographic identifier (hash) from the previous block and a timestamp.

4. The hash of the new block is calculated whereby a method to easily prove the validity of the block in the future is applied. This can be handled in the form of Proof of Work (PoW), Proof of Stake (PoS) or other consensus mechanisms, see below.

5. Finally, the participants take a vote of whether the final block including the newly calculated hash is valid. If the majority votes in favor every node in the network will append the block and it thereby becomes part of the blockchain and cannot be altered anymore.

Figure 2.1 depicts the structure of a block as portrayed by Lin and Liao [LL17]. A block contains the data of the N transactions or other types of information called "Main data" in the figure. The header of every block stores a timestamp, the hash of the previous block and it's own hash as well as other miscellaneous information depending on the application.

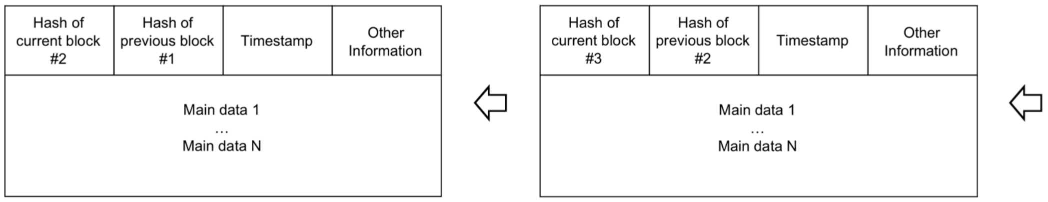


Figure 2.1: The structure of a block within the blockchain as portrayed by Lin and Liao [LL17]. Each block contains the main data of information / transactions as well as a timestamp, the hash of the previous block, the hash of the current block and other miscellaneous information.

Hashes are an essential part of the structure of blockchains. They are incorporated in a way so that they ensure that previous data cannot be tampered with. A hash is a sequence of characters that uniquely identifies data without giving away the data itself. The calculation of a hash should be easy knowing the data. However the other way round, given only the hash it should be practically impossible to calculate the data as described by Di Pierro [DP17]. This is solved with a mathematical function which also must ensure that two data inputs cannot produce the same hash output. Hashes are used widely in various other areas of computer science, for example a typical usage is the encryption of passwords. As seen in Figure 2.1 hashes are used to connect blocks to each other. By including the hash of the previous block in the calculation of the hash of the current block, they become uniquely linked together. If the previous block was changed, the hashes of the following blocks would become incorrect and would need to be recalculated. However such a recalculation with malicious intentions is hindered by the following mechanisms.

Consensus Mechanisms

There is a number of mechanisms that verify the validity of data in a new block of the blockchain. They aim to protect from malicious attacks such as manipulating previous data. The three most common mechanisms are called Proof of Work, Proof of Stake and Proof of Authority.

- Proof of Work (PoW)

  PoW is among others applied in the two most popular blockchain systems Bitcoin and Ethereum as Li et al [LJC+17] state. Ammous [Amm16] explains Proof of Work as a mathematical operation that is performed simultaneously by several nodes for each new block. This is a time-consuming and, in terms of processing power, costly operation to prove that *„work“* was being put into creating each new block. The value is called a *„Nonce“* and is a random value that does not contain meaningful information. The Nonce is calculated to achieve a certain target value for the blocks' hash value after adding this Nonce to the new block's data. Or in other words, after the Nonce was appended to the block, the blocks calculated hash value should equal a certain target value. Therefore, it is easy to verify by applying the hash function and checking whether the result equals the target value. Calculating such a Nonce value is difficult as hash functions are designed so that it is practically impossible to reverse engineer the required data to achieve certain hash target value. Therefore the *„Nonce“* value must be essentially guessed by trial and error as also described by Lin & Liao [LL17].

The first network participant that successfully found this value is financially rewarded for their expended processing power and shares the result with the other nodes of the network. These can then stop their own attempts to calculate this value as they have received the solution and are not rewarded.

The purpose of this mechanism is to slow down the generation of new blocks, as Lin & Liao [LL17] explain, to one block every 10 minutes in the case of Bitcoin. Hackers would need to recalculate the Nonce after manipulating the data so that the new hash value would fulfill the target value again. This would take them time and as new blocks that are chained together keep being generated, this becomes nearly impossible. The further back in the past hackers want to manipulate data the harder it becomes as all the following hashes will have to be recalculated as well. However the necessary processing power and thereby electricity as well as the slow block generation are problematic drawbacks of this mechanism.

- Proof of Stake (PoS)

  An alternative to PoW is the Proof of Stake method which is often favored due to its properties of not needing as much expensive power and more fairness in the winning miner selection according to Lin & Lao [LL17] and Romano & Schmid [RS17].

  This method uses a probability based on the number of coins owned by the miner. The more coins the miner owns the higher are the chances to generate a new block. In order to avoid accumulation of coins and hashing power mechanisms such as using factoring coin age into the probability can be used as Romano & Schmid [RS17] explain. As Lin & Lao [LL17] further describe, Proof of Stake might provide more security because hackers would need to acquire enough coins which makes it expensive and also less attractive as therefore they might suffer from their own attack.

- Proof of Authority (PoA)

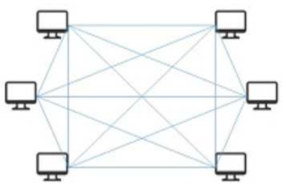
  In contrast to the previous proof mechanisms Proof of Authority is based on an already established authority that can be trusted. This is similar to traditional systems where a central authority holds the database and monitors the validity of data [Mat16]. This mechanism is primarily used in private blockchains where one or several trustworthy nodes generate new blocks that are proposed to the network as described by Dinh et al. [DLZ+18]. This method is often criticized as it bypasses the main advantage of a blockchain system which is to avoid a trusted central authority or intermediary.

There are several other mechanisms that are used in blockchain systems such as Delegated Proof of Stake (DPoS), Practical Byzantine Fault Tolerance (PBFT), Proof of Elapsed Time (PoET), Proof of Burn (PoB) as listed by Dinh et al [DLZ+18] and Li et al. [LJC+17]. Mattila [Mat16] also provides an overview table of different consensus mechanisms in the appendix of his work. However most of these are variations of the above mentioned proofs and are beyond the scope of this work.

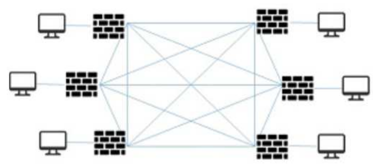
The procedure of adding a new block to the blockchain ends with a consensus between the network participants. They continuously vote which version of the data is accepted as authentic. The version with the majority is considered valid. As Mattila [Mat16] further explains, in order to avoid dishonest votes it is rewarded to vote with the majority and punished to vote against the majority. This incentivizes participants to create one shared consensus database while maintaining a structure without a leader managing the shared data.

2.1.3 Two basic types of blockchain systems

As briefly mentioned within the proof mechanisms, blockchain systems may have already established trusted actors. Mattila [Mat16] describes the difference between two types of blockchain systems: permissioned and permissionless. Lin & Liao [LL17] also describe this difference but naming the types private and public blockchains. They depicted them in a simplified way which is shown in Figure 2.2 as a visual reference. For this work, the distinction between these types is notable to argue why there are different technological approaches that are suitable to achieve different characteristics in blockchains such as the methods PoW, PoS or PoA described above.



(a) Public/Permissionless blockchain



(b) Private/Permissioned blockchain

Figure 2.2: A simplified visual depiction of public/permissionless vs. private/permissioned blockchain types by Lin & Liao [LL17]

	Permissioned	Permissionless
Fast	☑	☐
Energy-efficient	☑	☐
Easy to scale	☑	☐
Censorship-resistant	☐	☑
Tamper-proof	☐	☑

Table 2.1: Simplified depiction of the trade-offs of characteristics between the two types of blockchain systems: permissioned and permissionless by Mattila [Mat16]

Permissionless, or also called public, systems are designed to be open to anyone - no permission needed to enter the network. However as participants are unknown to each other, trust must be established through other incentives such as monetary or game-theoretical incentives. An example of such incentives is described in Proof of Work. Whereas permissioned systems proceed on the assumption that all participants are known or can be trusted to vote honestly. Therefore artificial incentives don't need to be incorporated which often come with drawbacks of additional costs on power, scalability restraints or efficiency. However permissioned systems are less secure, immutable and censorship-resistant.

While various incentive and structural mechanisms such as different types of proofs are constantly being improved or redesigned, so far by design there have always been trade-offs to make in order to achieve certain desired characteristics. As blockchain systems can be designed in multiple ways on different layers, the consequential characteristics will always depend on the specific constellation of such design choices and can therefore not be ascribed to blockchains in general. However, Mattila [Mat16] outlines a simplified overview of two basic categories of blockchain systems, permissioned and permissionless, and their inherent trade-offs as shown in Figure 2.1.

2.1.4 Applications

While Nakamoto [N+08] designed the blockchain system tailored to the cryptocurrency Bitcoin he thereby laid the foundation for many other possible applications. The unique features of a blockchain system, in particular the ability to provide immutable, distributed and transparent yet anonymous records are advantageous in other areas as well. As Mattila [Mat16] points out, these features are especially useful for various records of ownership. This section outlines a few examples of blockchain applications besides cryptocurrencies.

– Asset Management

  Probably the first application that comes to mind is managing other digital assets as there are many similarities to digital currency. Dinh et al [DLZ+18] refer to it as "pieces of data with attached real-world value" which applies to any digital assets, including cryptocurrency. The main difference is that digital assets are issued by entities outside of the blockchains, making the blockchain system only a place to record existence and ownership changes. Xu et al. [XZZP17] further explain that the timestamps and tamper-resistance of blockchains offer protection for intangible assets such as intellectual property rights or domain name management. Tangible assets on the other hand can be managed when combining the blockchain technology with the technology of the Internet of Things (IoT).

– Internet of Things (IoT)

As many ubiquitous networks are based on centralized architecture, it forces companies to operate within the framework of one network controlling company as Mattila [Mat16] argues. On the one hand centralized networks are often easier and cheaper to construct and maintain. However when trust is of importance or when companies cannot come to terms of who would control the network, a blockchain system can be useful in order to create a system every participant can trust in and would therefore allow for interoperability between platforms of different companies. The blockchain would act as a trustable neutral shared platform to exchange data without a dominant player.

– Supply chain records

This idea of combining the Internet of Things with the blockchain technology can also be extended to supply chain management of products. Here, the blockchain can be used to trace information on products such as origin of materials or ethical and safety aspects of manufacturing. This way consumers are able to make a better informed decision of which product and company they want to support through their purchase as Mattila [Mat16] points out.

– Nanopayments

Mattila [Mat16] explains that the blockchain technology makes even very small payments of less than a cent economically feasible. Such small payments would otherwise be outbalanced by fixed costs or technological or organizational limitations. For example, nanopayments can play a role for online content creators who could charge small amounts per view rather than relying on advertisements or product placements as an income.

– Health Care

As trust and security can be provided by blockchains it is a promising technology for healthcare systems as Romano & Schmid [RS17] and Xu et al. [XZZP17] argue. It can further improve interoperability issues when sharing medical records between different healthcare entities which could improve the quality of medical care according to Tama et al [TKPR17]. With healthcare data the aspects of security and immutability become particularly important as they are highly confident and private and should therefore not be misused.

– Other possible application scenarios include identity certification, notarization, online reputation, international payments, insurance, and voting as mentioned by Mattila [Mat16], Lin & Liao [LL17], Miraz and Ali [MA18] and Xu et al. [XZZP17].

2.2 Blockchain in the Energy Context

The blockchain technology also offers many promising opportunities in the energy context. The energy sector is besides the financial sector furthest ahead in the development and research stage of blockchain applications, according to the World Energy Council [CP17]. This high interest is because blockchain could increase trading volumes and transactional speed as well as reduce waste and transportation costs [CP17] [SYZ16].

According to Chitchyan & Murkin [CM18], who reviewed blockchains within the energy sector, both academia and industry expect the blockchain technology to play a vital role in the potential future transition to a smart electricity grid. The main benefit is the decentralization given the development and increased popularity of electric vehicles and photovoltaic installations among consumers. For electric vehicles blockchain could serve to find nearby charging stations as well as to integrate them into an IoT network and subsequently enable various uses for smart contracts (see subsection 2.1.2 Blockchain Technology Overview / Computational Logic) between devices and control data without an intermediary.

Similar to supply chain records (mentioned in subsection 2.1.4 Applications) blockchain could also be used to prove where and how energy was produced and whether it was produced with renewable resources giving consumers the chance to make an informed decision on where to obtain energy from.

Analogous to the idea of using blockchain as a platform for payment transactions, it can also serve as a platform for energy transactions.

An example for such an application is peer-to-peer trading of energy in neighborhoods. Here, the blockchain network manages and records transactions almost automatically as Basden & Cottrell [BC17] describe, allowing consumers and small energy generators (such as private photovoltaic installation owners) to monetize their assets when they don't need them at the time according to Andoni et al. [ARF+19]. Several projects are already live and/or currently being beta tested such as Enerchain [Ene], Alliander [All], Grid+ [Gri], Greenum [Gre] and more as Chitchyan & Murkin [CM18] listed.

Chitchyan & Murkin [CM18] also present a more detailed table of companies working with blockchain in the energy sector showing that blockchain is not only of interest in research but also in the industry as well as showing that there is a wide breadth of areas and purposes for blockchains within the energy context.

Changes inherent in the nature of blockchain and typical for a new technology can be observed such as enabling new services and businesses that haven't existed before and eliminating intermediaries. However besides these developments, according to Chitchyan

& Murkin [CM18] another interesting change can be noticed which is the change of the role households play. They not only represent consumers anymore but also take a more active part by investing into energy installations and becoming active sellers of their own produced energy. This change was possible as previously households have been considered too small to take part in selling energy as the infrastructure needed was too expensive and would take away from revenues and business opportunities of intermediaries and established energy providers. Using blockchain many of these costs are eliminated or reduced and households are even encouraged to take on this active role by new businesses. However in this way, it becomes more important to sufficiently familiarize non-expert users with this new backend technology so they could participate and benefit from these new opportunities if they wanted to.

In this work, the energy context, in particular peer-to-peer energy trading was taken as a use case to demonstrate where blockchains are used and how this could affect people. This use case was chosen because, as described above, in order to take part in such applications users must take an active role and an active decision for doing so. For which in turn it is necessary to inform people on their possibilities and options so that they would be able to decide whether they want to take these active steps and how to do so.

2.3 Learning Methods and Theories

The research question or goal of familiarizing non-experts with the fundamentals of blockchain technology equally deals with learning, or better even teaching as it does with the blockchain technology itself. Under the assumption that the typical non-expert who might be interested simply out of curiosity or because they might be interested in using a blockchain technology is looking for a quickly available, easily accessible information, digital learning methods come to mind. Digital learning methods can be of different forms that speak to different people.

In this section different styles of learning are distinguished and how they can be applied to digital learning methods for this work. Visual, verbal and interactive learning and learning by playing are described. However, there are many other ways to classify learning methods such as the Myers-Briggs Type Indicator [MMM85], Kolb Learning Style Model [Kol14], Hermann Brain Dominance Model [HN89] or the Felder-Silverman Learning Style Model [FS+88]. The latter is partially considered in the following paragraphs. This differentiation was chosen to directly apply to different forms or details of digital learning methods. Finally, different learnings from various evaluated digital learning methods or learning methods for contents of technical nature were collected.

2.3.1 Visual & Verbal Learning

„Learning styles refer to one's preferences in processing external information or internal knowledge and experience.“ as described by Hsieh et al. [HJHC11]. For this work the external information is relevant as the content of blockchain technology will be new

to non-experts or can otherwise serve as a refresher to already familiar people. This external information also relates to the dimension of input which Felder et al. [FS+88] describe as a sensory channel that enables to perceive external information. This is one of five dimensions to describe a person's preferred or most effective learning style which according to them can be classified as visual or verbal. People associating with the visual learning style absorb visual information best such as in images, diagrams, videos or demonstrations. People associating with the verbal learning style on the other hand absorb verbal information in written or spoken words best such as in presentations or reading texts.

Visual Learning

Almost 40% of college students are visual learners as Clarke et al [CIFY06] found in literature. Janitor et al [JJK10] describe visual learning as a method in which various types of information is represented graphically or associated with images and animations. These associations can help to better remember and use the new information. They further believe that visual learning supports learning more abstract subjects that require a higher level of imagination and name computer networks as an example. Using animations and practical examples help students understand more efficiently. This matches what McGrath & Brown [MB05] argue, that visuals allow to communicate more complex and subtle concepts and would engage students to a higher degree in the presented ideas. In their study, Clarke et al [CIFY06] investigated visual summaries and found that even people who don't have a visual learning preference benefit from visual instructional materials. Alongside many potentials of using visuals for learning, McGrath & Brown [MB05] also remark that they can be irrelevant or even misleading and should therefore be examined critically and applied with caution.

For this work, this could be applied by incorporating images or animations in the prototypes. Especially as blockchain technology can be considered a more abstract subject for most non-experts that however will need to be simplified to represent only what is helpful to them. As the prototypes will be of digital nature, a range of visuals can be included.

Verbal Learning

Verbal communication is somewhat of a standard and includes according to Felder et al. [FS+88] the *„traditional“* learning methods of lectures and books or scripts which we are most used to. This includes both spoken and written forms which makes up how we communicate through language. Kirby & Moore [KMS88] reason that verbal learners tend to apply elaborative strategies which could be written summaries, flash cards decks, reading and writing notes, writing something by hand and more. Northcraft & Jernstedt [NJ75] found that college students who received outlines or lists of examples had higher examination scores than students who received transcripts or no supplementary materials.

In order to include verbal learners in prototypes of digital learning methods such as videos or websites, text or overviews in bullet points could be shown. Or in the example of the video, explanations could be spoken in addition to the visual images or animations. Technical words that are not in the vocabulary of non-experts should be explained directly in everyday language.

2.3.2 Interactive Learning

In this section, interactive learning is understood as ways for learners to become active, interact or engage with contents, the learning method, learning tools or their learning process itself.

There are different positions of learning and teaching which relate to interactive learning. Three puristic and historically grown positions for learning are behaviorism, cognitivism and constructivism as summarized by Göhlich et al [GWZ07].

Behaviorism approaches learning by behavior and involves concepts around teaching with repetition, temporal proximity and extrinsic motivation. Cognitivism approaches learning as an interplay of internal processing of information form external sources. In the constructivist view people are a closed informational system which means that perceiving, recognizing and learning are processes of internal construction rather than processing of external information. Bruner [Bru74] and Ausubel [ANH74] brought up theories for forming cognitive structures. In Bruners [Bru74] theory, learners should be encouraged to discover principles themselves, find information, construct hypotheses or rules and be able to solve problems within them. Ausubel [ANH74] argues a subsumption theory where new information is related to relevant previous knowledge by meaningful receptive learning.

A controversy described by Peters [Pet00] relates to these positions and theories. It is about the nature of learning between who he calls traditionalists versus progressives who stand behind expository versus autonomous learning. He describes that progressives believe that the traditional view that a group confronted with the same content would absorb the same amount and portions of information is an illusion. Instead, a more active approach should be encouraged. By including ways to engage with the contents as well as their learning process on their own, learners are enabled to and also learn how to autonomously obtain knowledge. Another important aspect is to be able to cooperate with others. Peters [Pet00] believes that both approaches remain important.

Another dimension by Felder et al. [FS+88] is the processing dimension which is divided into either active engagement or reflective processing. This relates to King's [Kin94] approach who describes three different types of questions to guide students' knowledge construction: memory questions which lead to factual, straight-forward answers; comprehension questions asking learners to describe something in their own words or connection questions which lead to higher-level answers of interpreting or interlacing the knowledge within multiple concepts. King [Kin94] suggests to start with lower-level questions before moving onto higher-level questions to enhance comprehension.

Asking memory questions is a way of interactively engaging with contents. This can rather easily be included in most digital learning methods such as for this work. For example digital learning methods allow to include multiple choice questions which could serve as memory questions. The result of the multiple choice answer can be directly computationally evaluated without much effort since they are not open textual questions.

2.3.3 Learning By Playing

Games were found to be both effective and motivational for learning. They are considered in this work as they are a form of digital learning that has become more and more popular, especially on mobile smartphones. Literature shows different reasons of why playful activities are beneficial for learning, some of them are collected here.

A theoretical approach by Baumgartner et al. [BLW00] is also based on the differentiation of the historically grown learning positions behaviorism, cognitivism, and constructivism (which were briefly mentioned in the previous subsection). They argue that in particular the constructivist learning is relevant for playful learning as students have to develop possible solutions to challenges and manage complex situations. Koster [Kos13] explains that in games, players must recognize patterns, discover variations and moreover understand the rules which can form aspects of reality that users learn while playing. This thought is also supported by Squire and Jenkins [SJ03] who explain that games force players to form theories and can motivate them to turn to textbooks to better understand these theories. However Garris et al. [GAD02] warn that while pairing game aspects with instructional teaching content can bring great learning effects one must be careful not to overwhelm the playful aspects with the learning goals. They draw attention to the tension between play and work, being that play is free, voluntarily, nonproductive and separate from the real world, which differs from work and learning. They further argue that for knowledge construction support must be provided by instructors for example in the form of debriefing.

Playful learning could be interesting for this work as some non-experts who are interested to voluntarily learn about blockchain technology in their leisure time might already associate learning about it with fun and therefore a playful approach might appeal to them. The constructivist learning aspect could be taken advantage of by getting players to construct different aspects of the blockchain technology in order to understand them better such as a hash, a concatenated hash forming a chain, a distributed network, a consensus votum and so on.

2.3.4 Learnings from Digital Learning Methods

Despite the fact that there is little literature on specifically teaching blockchain technology, there are still several learnings from other related works that can be used as reference. In this way, literature on the methods for training and learning that could be considered for conveying blockchain technology can provide recommendations and advice on the selection and the design of the learning methods, to name a few:

- Martin & Dunsworth [MD07] evaluated a Computer Literacy Course and found that hands-on projects, activities and demonstrations were helpful to students while long lectures and online quizzes were not.
- For graphical illustrations Vekiri [Vek02] suggests they are effective when they ask for little cognitive processing to interpret the presented information.
- McLaughlan [McL07] found role plays and scenario building to be well suited to provide an understanding for the interplay of multiple dimensions in complex technical applications.
- Olfman et al. [OBS14] included best practice guidelines for training strategies in their work, one of them being that collaborative learning in teams, pairs or communities is promising as well as behavior modeling followed by hands-on practice is suited for learning sequences.
- In a comparison study Choi & Johnson [CJ05] found that video instruction has effects on increased attention and is according to learners more memorable than traditional text-based instruction.
- Spiegel et al. [SMH+13] also conducted a comparison study between comics and essays finding that comics are equally effective but increased interest in teenagers who had low science identity. However in another study about learning with comics Durik & Harackiewicz [DH07] found that added colors and pictures demotivated already interested students. They suppose it may have distracted them or appeared too childish.
- McGrath & Brown [MB05] draw attention to the idea that images sometimes need to be simplified for understanding a specific part. They describe the rules of a medical science animation developer Drew Berry, in which the amount of detail plays a major role. His animations convey only one concept, though with a lot of scientific detail. However any other environmental detail or irregularity within the style of the animation shouldn't distract or confuse.
- Mayer & Moreno [MM02] present seven principles for instructional animations which include in shortened and simplified terms simultaneous animation and narration, excluding irrelevant or redundant distractions, and use conversational language rather than formal.
- Kiili [Kii05] emphasizes a positive user experience in his experiental gaming model for educational computer games. Among others it is important to provide immediate feedback, clear goals and challenges according to the players' skills.

Findings like these can help in the conceptualization and the design of learning methods for blockchain concepts. A theme of keeping teaching material simple and without distractions is apparent while getting students to engage with the presented information.

2.4 Related Work

Blockchain technology only recently started to emerge in the HCI field around 2017. However general interest is increasing which for example a workshop at the CHI conference in 2018 [ENJ+18] indicates. Elsen et al. [ENJ+18] also argue that there is lots of room for essential research in the field of blockchains for the HCI community.

As the field has just recently emerged in the HCI community, there is little related research on the proposed problem of conveying the fundamentals of blockchain technology to users without technical background.

Maxwell et al. [MSC15] attempted to engage their study participants in the blockchain technology by opening up dialogue and interest through an interactive Lego game. In the game, participants received resources and money represented by Lego blocks. They were given the task to trade using blockchain principles. In verbal agreement, they would document the transactions on a Lego base plate by placing the payment Lego blocks with ownership marker stickers on them. Part of the group was assigned maths puzzles. Whenever they completed puzzles, transactions had to be paused and were then sealed with a new Lego base plate on top of them - resulting in a layered Lego block house. Their study results showed that as expected their approach did not easily nor fully explain the blockchain technology, however created an environment to learn and ask questions.

Treiblmaier and Zeinzinger [TZ18] applied a gamification approach to explain principles of blockchain technology. They adapted the Chinese board game 'Go' in a public installation where individuals could join teams to collectively agree on the next move of the stones. The moves were then displayed on a wall of the 'Kunsthaus', a public building in Graz. In qualitative interviews they then evaluated that the game increased the general understanding, and thus argue that gamification is a viable instrument for this purpose.

Next to these scientifically published articles on methods for explaining the blockchain concepts, several videos, comics and graphical illustrations on this topic can be found in non-scientific resources online. These can represent other approaches to engage users in the understanding of the technology however do not include an evaluation of their teaching effectiveness or how they appealed to people in other measueres.

CHAPTER 3

Methodological Approach

In order to answer the research questions presented in section 1.2, a methodological approach along a slimmed-down cycle of user-centered design was chosen.

User-centered design (UCD) is a broad term to describe approaches based on understanding and involving users and putting their needs in the focus. It should enable to design systems that would be usable and useful for people as Mao et al. [MVSC05] describe. The term and approach behind User-centered design has become widely used after the book *„User-Centered System Design: New Perspectives on Human-Computer Interaction“* by Norman & Draper [ND86] was published. UCD is represented in the International Organization for Standardization (ISO) under ISO 9241 (before ISO 13407). In its essence it comprises of a human centered process of four stages. Starting with understanding the users' needs (1) where various user research methods come into play. This is further interpreted to user and organizational requirements (2) which are then used to develop design solutions (3). Finally, an evaluation (4) of these design solutions is conducted and analyzed before either concluding that the users' needs are met sufficiently or restarting another cycle from the first stage. Characteristic for UCD is that this cycle is performed iteratively and involves users early on as well as in the evaluation.

This work represents one of such UCD cycles and concludes with findings from the evaluation of three design solutions and thereof derived recommendations. In the following the used methods and how they were applied in this work are described.

3.0.1 Literature research

In literature, information on the functioning and applications of the blockchain technology was collected as presented in 2.1. More attention to applications and impacts on non-expert users was paid to blockchain in the energy context, see 2.2, as this is the example this work will use in the learning methods.

In the second part of the literature research, different learning methods that are relevant for this work were researched and examined for possible implications in 2.3.

Finally, previous studies on methods for increasing users' understanding for the blockchain technology were examined in 2.4. These results should further inspire this work as well as give first directions from their learnings.

3.0.2 Requirement Analysis

A previously held blockchain focus group within the context of a workshop with non-experts informed the requirements for the learning methods from the perspective of potential users. The workshop was held as part of the research project by colleagues before the work on this thesis started. According to Wilson [Wil97] and Kitzinger [Kit95] two of the main advantages of focus groups is a non-threatening environment and unfolding group interactions that lead to more natural conversations between the participants rather than exclusively guided by the facilitator. Wilson [Wil97] collected a number of definitions in literature and summarizes the key elements of a focus group as being held by a facilitator with a small group of 4-12 people who keeps the attention on previously selected topics while giving them room to discuss their opinions, perceptions, ideas etc. Kitzinger [Kit95] further phrases the focus group as a special form of group interview. Lastly a natural advantage of this method is to gather a broad range of opinions from several people quickly.

In the workshop, the 16 participants were for the most part split into 3-5 groups in which they acted as a focus group to discuss the presented topics and questions. The aim of this workshop was to gain first insights into how participants perceive the blockchain technology currently, how much they already know and to compare first rough drafts of learning methods to make out preferences as well as advantages and disadvantages which would be used to decide on the types of learning methods to be developed and further compared in this work. The contribution in this work is the analysis of the provided data as part of the requirement analysis for the concept and design of the learning methods. The workshop and it's results are presented in 4.1.

Expert interviews that were self-undertaken for this work further informed the requirement analysis from a different perspective. Flick [Fli18] describes the characteristic feature of this method as being a semi-structured interview where the interest in the interviewee lies not in their person but in their role as an expert for a certain field or activity. This means that through their collected practical knowledge they do not represent a single case but a group to which this knowledge applies. As in other forms of qualitative interviews, the questions are worded open-ended to stimulate participants' answers without suggesting the answer within the question. This method was chosen to complement the insights from the above described non-expert workshop with different perspectives of professionals working in the field and their experiences.

Three experts from the blockchain field, both research and industry, were interviewed individually for about 30 minutes each. The semi-structured interview guideline focused on questions around the way blockchain would integrate into peoples lives and whether or not it is important to inform them of characteristics of the technology and how this knowledge would be important to them if at all. Experts were asked on their previous experience with users, how they perceived the users' knowledge and whether they have any personal insights or opinions on this matter. The expert interviews are further elaborated in 4.2.

The combination of the expert interviews and the workshop with non-experts formed the basis for the requirements for the contents and shape of the learning methods which are presented in 4.3.

3.0.3 Concept and Design

After learning about the requirements for informational material on basic fundamental blockchain concepts, three methods for conveying this information were conceptualized and designed. Such methods may have included variations of graphical illustrations, videos, educational games, comics, workshops or similar and were decided based on the results of the previous steps. The chosen methods are an animated video with voice-over, a mobile learning game for smartphones and a website. In chapter 5 the prototypes are described in further detail as well as why these particular learning methods were chosen.

It was necessary to keep the prototypes as similar as possible so that the user study would reflect the differences of the learning methods to a higher extent. For this reason elements such as wording, imagery or order of information were kept as similar as possible. To achieve this, the contents for all three prototypes were first set based on the requirement analysis before creating a guideline for the order of these contents. Peer-to-peer energy should be incorporated into explanations as examples and in the imagery. The same multiple choice questions divided the contents of all three prototypes into smaller portions of information which was intended to keep the learners more active by allowing for interactivity as well as to review information directly. The tools and procedure with which each prototype was created are described in detail in chapter 5. However for the ideation as well as for the design of imagery, layout and game elements the method of sketching was used, particularly for the video and the mobile game.

Sketching as a way of lo-fidelity prototyping on paper has proven to be useful for designers as a tool to play with ideas, to externalize them from the mind onto paper and as Craft & Cairns [CC09] further describe, sketching allows to creatively explore ideas that may not be fully formed yet. Buxton [Bux07] underlines that sketching is about design, not just drawing. He promotes sketching as a fundamental tool and in his books describes techniques to generate and elaborate designs as well as to make design choices and reduce between ideas that were put onto paper. According to Roberts et al. [RHR15] this also helps to organize and make explicit thoughts which would then eventually be turned into an artefact. Craft & Cairns [CC09] found that it not only improves design, collaboration and the design process but also supports short- and long-term memory, lateral thinking and modeling which all enhance creativity.

3.0.4 Evaluation

The prototypes were then evaluated and compared in a user study which is described in further detail in chapter 6. Using pre- and post-tests with multiple choice choice knowledge questions the effects on learning were measured for the first research question. The subjective level of comfort was quantified with a shortened version of the established user experience questionnaire (UEQ) by Laugwitz et al [LHS08] in the pre- and post-test for comparison values. Finally, for the levels of abstraction, different ways of explaining the same contents were taken from the prototypes and compared for favorability. Additionally a semi-structured interview was held at the end of each session to collect qualitative data for each of the research questions.

Pre- and post-tests are widely used to compare groups or to measure change from experimental treatments according to Dimitrov & Rumrill [DRJ03]. They further describe different experimental designs with control groups and how they can be analysed. With experimental and control groups one can compare posttest scores while considering pretest differences or compare the difference between posttest mean and pretest mean.

In this work, the latter option was applied, meaning there was no control group as the focus was to directly compare the learning effects of the learning methods. Participants were randomly assigned one of the three learning methods. Participants of a control group would have been given the pretest and posttest directly after one another without an intervention or a period of time in between where change such as maturation or history effects could have occurred. Gribbons & Herman [GH96] describe this as a quasi-experimental design with nonequivalent group and pretest-posttest. Due to the pretest, initial differences can be observed and taken into consideration for the analysis. The design of the user study and the pre- and posttests is described in chapter 6.

The pretest and posttest further included a shortened version of the User Experience Questionnaire (UEQ) by Laugwitz et al [LHS08]. Schrepp et al [SHT17] describe it as an established questionnaire with 26 semantic differentials that is used to quantitatively measure people's subjective impression towards the user experience of a product or service. The questionnaire relies on peoples spontaneous judgement without thinking according to Laugwitz et al. [LSI+09]. While the UEQ is intended to measure people's subjective impression towards the user experience of a product or service, it is used in this work to measure people's subjective impression towards the theoretical concept of blockchain technology itself without focussing on a specific application. Those adjective pairs that are relevant for the usage in this work and that are not dependent on a specific application were picked out and thus created a shortened, and to this purpose adjusted version of the UEQ. Thereby the questionnaire was shortened to 17 adjective pairs. The style of this questionnaire method allowed for easy and efficient analysis which is why it was applied in the pre- and posttest to measure how the subjective impression towards blockchains changed from before and after learning about the technology. This was then used to answer the second research question on the level of comfort towards the technology from a quantitative side.

Finally, a semi-structured interview was conducted with each participant at the end of the sessions after completing the posttest in order to collect qualitative data. Different from structured interviews, semi-structured interviews are conversational and as the name suggests partially structured. Longhurst [Lon03] describes that while a prepared list of interview questions is used, an open response in the participants own words is encouraged, also allowing them to explore issues they feel are important. Wood [Woo97] also explain, that in semi-structured interviews, interviewers can use their diverse set of prepared questions spontaneously in opportunistic ways, depending on the situation. Furthermore, Barriball & White [BW94] characterize them to be suitable to explore the interviewee's perceptions and opinions. Therefore, this method seemed appropriate for this work as the participants opinions towards learning methods and levels of comfort or abstraction could be explored in a sensitive, active-listening manner.

3.0.5 Analysis of Evaluation

As the study was designed in a way that the collected data would give insights to the research questions, they were also analysed that way. This means, that for each of the three research questions, quantitative and qualitative data was collected and analyzed. The results for each research question and how they were obtained are described in chapter 7.

The collected data from the pre- and posttests formed the quantitative part. It was digitalized from the paper questionnaires and then quantitatively analysed. Numerical values such as means, differences, percentages and ranges were used to describe the results. Furthermore, graphical illustrations of this data using colors were used to aid in understanding and interpreting the data.

The collected data from the semi-structured interviews at the end of the sessions formed the qualitative part. A process based on the thematic analysis was used to analyze the data. Evans [EL18] describe this method as a *„process of identifying patterns and themes within the data"*. To find such patterns and themes one has to repeatedly read and immerge oneself in the data to start achieving an overview of themes as Mazaheri et al. [MEH+13] describe. Evans points out that the research questions should be kept in mind when searching for themes so that the resulting findings would be meaningful to the study. Another matter to be careful about, as Graneheim and Lundman [GL04] remark, is the balancing act of adding meaning and subjective interpretation (which forms the themes) to the data and overinterpreting something that is not really there. While there are more thorough ways of performing a thematic analysis, such as the step-by-step guide Schmidt [Sch04] presents, a more simplified version was applied in this work. Essentially, the notes that were taken during the interviews were already divided into subthemes within each interview. These notes were then collected into up to three lists of notes and quotes for each research question from all thirty interviews. This process already required to read and reread the interview notes several times to place them into the according lists. From there, it was easier to find themes. This process for each research question and the results are described in more detail in chapter 7.

CHAPTER 4

Requirement Analysis

As described in chapter 3 Methodological Approach, the requirement analysis was comprised of two main parts: the previously held workshop with potential non-expert blockchain users and expert interviews. In this chapter the two parts will first be described individually before concluding with the requirements that were considered in the concept and design of the learning methods.

4.1 Workshop

As part of the research project, a workshop with 16 non-expert potential blockchain users was carried out before the beginning of the work for this thesis. The project partners kindly provided the data and some impressions of their workshop to analyze for this thesis.

The workshop took place on an evening during the week with a duration of 3 hours in September 2018. Participants were acquired through the Urban Pioneers Community, a project of the 'Viertel Zwei' neighborhood and Wien Energie, Austrias largest energy provider. As a way for the residents to engage in the development of the infrastructure they offer workshops, interviews and other events for members of this community, rewarding them with points that can be used as vouchers for services. For this workshop, participants received points equivalent to 14 Euro. However these events have developed to be a social gathering for neighbors to connect as well.

The 16 participants were roughly in their thirties to fifties and about half female and half male. It should be noted that residents of this neighborhood are generally often upper middle class with high education. This circumstance can be considered a limitation of this workshop as it doesn't represent the full range of potential users for blockchain applications in the peer-to-peer energy sector, let alone the full population. However, one can argue that private photovoltaic installations, solar energy installations or other equipment required to participate in energy producing and sharing are still considered expensive and therefore possibly only affordable from upper middle class upwards.

4.1.1 Associations

As a warm up exercise participants were asked to choose from a number of postcards with quotes and citations on the topic blockchain and peer-to-peer that matches their personal associations. Furthermore they should write in one or two short sentences why they selected this postcard. Figure 4.1 shows their associations with the reasons they wrote down in German language. As there are 17 associations but only 16 participants, one must have handed in a second association.

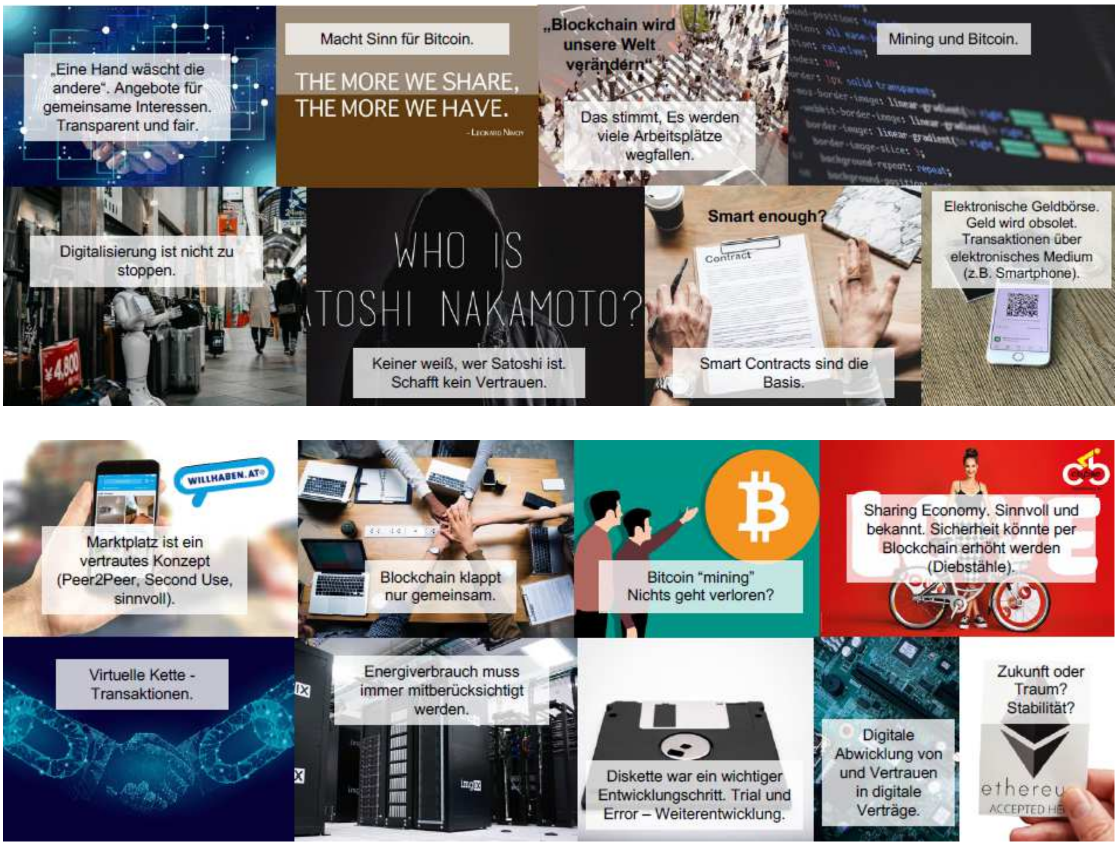


Figure 4.1: Participants' associations with blockchain as put together during the first task of the workshop in German language. See translations of significant quotes in text.

Their choices already show a certain sense for and knowledge of the blockchain technology. Participants jotted down some buzzwords from the domain such as 'transparency', 'mining', 'Satoshi Nakamoto', 'smart contracts', 'electronical wallet', 'virtual chain', 'transaction'. From this it appears some participants have at least a general understanding of blockchain while it remains unclear for other participants that put down rather general remarks about technology, digitalization and development. Some associations show a certain suspicion such as 'Future or dream? Stability?' or 'Nobody knows who Satoshi is. Doesn't create trust.'. Others appear rather positive such as 'One hand washes the other. Offers for mutual interests. Transparent and fair.' or 'Sharing economy. Makes sense and is well-known. Blockchain could increase security (thefts).'. Subjectively, 4 could be considered positive, 9 neutral and 4 negative associations. In this quick exercise none of them put down keywords that signify a deeper knowledge or understanding of blockchain.

This suggests that participants have different opinions and seem to have different levels of knowledge though almost all of them seem to have at least heard of blockchain before. However, 'blockchain' was also in the title of the invitation for the workshop, so it is possible that they did some quick research on blockchain before coming to the event.

4.1.2 Knowledge indicator

Participants were then asked to place stickers as answers to questions on posters in the form of Likert scales, yes/no or category questions. The posters were placed on walls in the room, they had no chronological order. The goal of these questions was to get an idea of how interested participants are in the technology, how and where they get information and how they've been involved with the technology so far. While they will be analyzed in the following, the precise data is represented in the Appendix in Table 1, Table 2, Table 3, Table 4, Table 5 and Table 6 which show the questions and the corresponding answers of the participants.

In Table 1 participants were asked how much they know about blockchain on a scale from "Almost nothing" to "I learned a lot about it". The answers indicate that 7 out of 16 participants know almost nothing about blockchain and 5 participants know little about it. Nobody placed the sticker in the field for knowing a lot about it, however 2 placed themselves in the middle of the Likert scale and 2 placed their sticker on 4 out of 5 in the scale. On average, participants stated to have a knowledge of 1,93 out of 5 on the Likert scale. The majority sees themselves as beginners with their blockchain knowledge and thinks they don't know a lot about it. Only few indicated they have some or a little more knowledge.

Asking whether they were personally involved with blockchain technologies before (see Table 2), 4 participants said Yes and 12 No. Three indicated it being in a trading and speculations context, one in a software development context. It could be assumed that these four indications were from the people, who said that yes they've been personally involved with blockchain before.

It is unclear whether these 4 people are also the same 4 people that placed themselves higher on the knowledge scale question. Unrelated of their involvement or knowledge so far, 10 out of 16 participants think that blockchain will have a high influence (Table 3) on our future and lives whereas only 2 think it has little influence. 4 participants are unsure. This result is interesting, as so many participants stated to know little about the technology yet still think that it will be a big influence. This could have many reasons, for example it could be attributed to the high coverage in media, their professional background or the fact that they are participating in a blockchain workshop.

In Table 4 the results to the question of how interested participants are presented on a scale of ”not at all” to ”very interested”. Most participants are in the middle field of the scale. The outer extremes are rare, only one person being very interested, and zero participants being not interested at all. There is a tendency for higher level of interest with 6 people being above the middle field and only 3 below. The average interest is 3,25 out of 5 on the Likert scale. To the question whether they're actively seeking information in Table 5, 5 participants stated Yes, 6 No and 5 'Yes and No'. This shows that not everybody who is interested is also actively seeking information. However a reasonable amount of more than a third does actively seek information.

The question of Table 6 was where participants have previously heard or read about blockchain. They placed their stickers on the corresponding sources of where they obtain information on blockchain - multiple stickers per person were allowed. 10 out of 16 learn about blockchain on social media, blogs and websites, 8 from newspapers and magazines and 6 from friends and family. Interesting is, that only 3 learn about it at work when in Table 2 4 stated to have been personally involved with blockchain. This means that either not everybody who learns from it at work also stated to personally have been involved with it or that at least one person was involved with it in his/her personal life. A third of the participants (5 out of 16) also get information on TV and 4 out of 16 in conferences, seminars or webinars. The latter again means that at least one person attends these events outside of the work context. It is possible that in both cases this person is the 'very interested' participant, however this is a speculation.

From these self estimation questions it appears most participants are beginners in their knowledge and only few would say they know a bit more. However the majority thinks it will have a high influence in the future. Participants indicated that they are interested to some degree but not highly interested. Most receive information online, from social media, in the newspaper and in magazines.

4.1.3 Learning methods

As a next step, three methods for explaining the blockchain technology were presented to the participants: a text, a graphical illustration and a video. The participants were split into three groups and were shown the learning methods on three hosted workshop tables, one for each method. After reading, looking at or watching the material, they were asked for their opinion on the comprehensibility, level of detail, type of learning method, and preferred channel for this kind of material, each having prompt questions for positive or negative aspects. From the second round, the hosts also briefly presented the opinions from the previous group before participants gave their feedback. Other than the knowledge indicator described in the previous paragraphs there was no examination of knowledge in this preliminary workshop. However such an examination was part of the later user study of this work presented in chapter 6.

The material for the learning methods in this workshop was rapidly put together by a project member in less than a day and inspired by various online materials. An article by Cloer on the Retarus Corporate Blog [Clo16] inspired parts of the text. It was heavily shortened and simplified. An example in the energy context was added and the important parts highlighted.

The comic was put together with free icons, the layout was inspired by the website Alphaslot [Alp] who used a similar graphical illustration to explain Bitcoin transactions.

Parts of the YouTube video created by the Centre of International Governance Innovation [Mos18] served as foundation for the video used in this workshop. It was cut to only include the minimum as a basic concept. Further, the text was translated and newly recorded in German. The subtitles were adapted accordingly as well.

Text

The quote in Figure 4.2 shows the text in German language [sic] as it was presented to the participants at the workshop. It consists of 176 words explaining the basic concept of the blockchain as a decentralized database and how its blocks are chained together cryptographically with hashes. As mentioned above it was rapidly put together by a project member and inspired by Cloer [Clo16] however shortened, simplified and an example from the energy context was added. The text includes some grammatical incorrectness which is likely due to the time pressure under which it was put together.

The text received mostly negative comments in all categories comprehensibility, level of detail and type of learning method. Participants noted several times that the text has raised further questions and was difficult to understand. The questions they wrote down as examples for what was unclear range from questions of general understanding like what blockchain is for, what is behind it, what the goal is, who it is for up to questions about the technology itself such as what a block is, what transparency means, what about the privacy, which software is required or what a copy, that everyone has, was exactly. This signifies that neither the general idea nor the technical aspects came across in the text. They further noted that the example is too abstract, that the text is inconsistent and that a combination of an image and text would be better. The feedback also said that the sentences are too long, examples are missing and readers are not addressed directly. A positive remark is that the advantages were highlighted in bold. From these responses it seems that the level of detail of the text was insufficient or the wording was not well chosen. It is a fine line between giving enough details, being very clear to answer all the questions and overwhelming readers with too much text and information and risking to lose their interest in reading it. It seems the participants had a hard time getting a picture of how blockchain works as they put down twice that a combination of text and images or a video would be better. Therefore it could be advantageous to provide such a combination of visuals and text so that readers can follow the content of the text easier and grasp more easily what it is trying to convey. As a preferred channel participants only put down one element 'Online/Internet'.

Was ist die Blockchain?

Die Blockchain ist eine **verteilte Datenbank**. Es werden Informationen gesammelt, verschlüsselt und an die Datenbank angehängt. Das Besondere an Blockchain ist die **Dezentralität**. Sie liegt nicht auf irgendwelchen Servern, sondern jeder Nutzer hat eine eigene und vollständige Kopie. Jede Veränderung wird **transparent** erfasst und es ist **fälschungssicher**, da es durch seine große Verteilung es nicht möglich ist es zu hacken. Änderungen an kann nur durch die Mehrheit der Beteiligten beschlossen werden.

Wie funktioniert die Blockchain?

Bei der Blockchain wird jede **Information in Blöcken** gespeichert. Zum Beispiel kann die Transformation vom Stromguthaben von einer Person zu einer anderen Person so eine Art von Information sein. So wird der Block, der zum Beispiel die Transaktion vom Stromguthaben hinterlegt hat, an alle Parteien im Netzwerk gesendet. Nachdem die Parteien die Transaktion bestätigt haben, wird jeder neue Block mit dem vorhergehenden Block verbunden. Die **Blöcke bilden ein Kette** und jeder Block enthält eine Historie in Form einer Prüfsumme. Zusätzlich enthält jeder Block auch noch die Prüfsumme der gesamten Kette. Damit ist die **Reihenfolge** der Blöcke **eindeutig**.

Figure 4.2: Text [sic] explaining the basic concept of blockchain as shown during the workshop (German language)

Graphical illustration - Comic

In Figure 4.3 the comic in German language as it was presented to the participants is illustrated. As mentioned above, it was inspired by Alphaslot [Alp], however put together with free icons and remodeled to show an example in the energy context rather than Bitcoin. The comic uses character icons, laptops and puzzle pieces as imagery. It conveys that a blockchain is a decentralized data base and that information is stored in blocks which are chained together. However, different from the text it leaves out the cryptographic linking through hashes. In total, the text in the comic contains 94 words which is just a bit more than half of the number of words in the text.

Similar to the text method, the comic also had many negative and in relation few positive comments. Many of them also centered around open or raised questions regarding the basic concepts. However it seems the questions are less specific on technical details than the questions that came up from the textual method. This could mean that participants were focused on the main idea and the comic didn't confuse them with details that may not be relevant to them or that the comic failed to convey such a main idea at all and therefore prevented detailed questions.

Furthermore it is interesting that participants noted that the text in the comic is easy

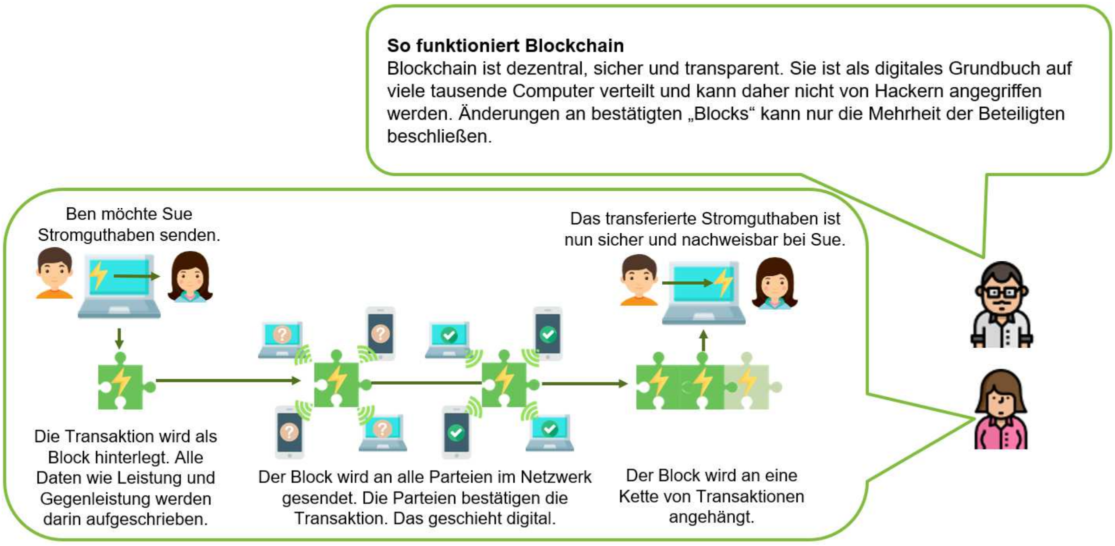


Figure 4.3: Comic explaining the basic concept of blockchain as shown during the workshop (German language)

to understand but that there are some elements missing such as a legend or whether the confirmation happens automatically. In the feedback they state that the imagery is sometimes unclear, that colors are missing, that it is cluttered, messy and that it barely creates added value. This is in contrast with the above assumption that the textual method would be supported by visuals. However subjectively it seems that the questions it raised for readers could be answered more easily with small additions or changes than the open points of the text method. It is possible that some adjustments to the wording, imagery and layout could solve some of the confusion and provide its readers with the basic knowledge as intended.

The participants didn't name a preferred channel for this type of material.

Video

The video showed was 1:05 minutes long and used simple imageray; depicting a block as a die and a chain connecting these dice. Other imageries included a mixer that mixed all the data into one substance and spreading it into the dice to symbolize that every die has the same information. As mentioned above, an existing YouTube video created by the Centre of International Governance Innovation [Mos18] was shortened and translated to German. A female voice explained the basic concept of blockchain in German language with corresponding subtitles shown at the bottom of the video.

The video received the most and also most detailed comments as feedback. It received the same amount of positive comments as negative comments for comprehensibility as well as for the type of learning method. Also, participants suggested 6 preferred channels for this type of material. Only the level of detail had a similar distribution compared to the other methods with more comments on the negative side.

The major content related points of critique were that examples are missing and that the end was confusing. Three questions were listed: *"What is the relation to Bitcoin?"*, *"What is mining?"* and *"Is the information to transactions saved on my computer?"*. The example had mixed reviews, some found it simple and easy to get started, others found it too technical.

On the realization of the video they negatively remarked on the resolution, sound quality and the enthusiasm of the voice. Participants said that they could not follow half way through as the information was delivered too fast. The level of detail was commented as adequate for the length of the video though. An interesting feedback point was therefore that the level of detail should be higher and hence the video longer. The comment stated that it doesn't come across how exactly it works. It would be interesting here to know how far and how much the participants still understood and whether that might be enough already. In this case it would be enough to give the video a rounded ending so that participants also feel like they understood the basic concept but that there would be more details to know if they were interested. It might appear to them that these details are essential even if they are potentially not. However if it is the case that participants actually didn't understand the basic concept then this video or even the method needs to be substantially reconsidered.

Aspects to keep in the next video versions should, according to the positive feedback, include the subtitles, the voice-over, the animations with simple symbolism and no background music. A general negative remark on videos as a tool to convey information is that the information is gone after watching if one doesn't remember.

Participants suggested various channels for this method. When delivered online they noted that the source needs to be trustworthy and it is important it has a serious appearance. They would like to see this material on social media, via e-mail with a link as the source is clearly evident (as example they named the Urban Pioneers Community), in magazines and books with a link or QR code that lead to the video, on TV to reach mainstream or on YouTube. Furthermore, they suggested that it could start with a beginners video that explains the main and basic concepts and continue with a series of subtopics. This way they can decide themselves whether they are interested and want to learn about this specific part in more detail. In general, participants seem to want to control the information themselves and be sure that it is trustworthy by being from a trustworthy source.

4.1.4 Summary and Conclusion

Participants in this workshop seem to have a general understanding of blockchain and could name several buzzwords around it. However there is somewhat of an uncertainty and suspicion towards it. Participants have mixed views on the technology. In the self estimation participants stated to have basic knowledge, only few stated to know more about it. However most participants think blockchain will have a high influence in the future. Participants are somewhat interested in the technology but not highly interested.

The video emerged as the favorite out of the three learning methods. It seems that visuals and imagery facilitate the understanding of complex interactions for non-experts. Text was often ambiguous for them and raised more questions. Text in general needs to be as easy as possible to understand and pick up readers with examples that they can relate to from their daily lives. It should be lively and easy to follow. Besides examples, participants also asked for visuals to be able to follow the text better. From the comic we learned, that the imagery needs to be clear and simple and that details in layout and design matter. The wording is still important and needs to go well with the imagery. The questions the comic raised seemed less focused on technical details. It is possible that the images focus the readers attention to the main concept rather than technical details that are not necessarily relevant to understand the basic concepts. The video received the best response, however some questions stayed open. Participants noted that the level of detail and length of the video need to be balanced well and so that it wouldn't be too fast to follow the presented concepts. Animations and imagery helped them understand as well as voice-over and subtitles helped them to follow. They further emphasized how important it is that it appears trustworthy and comes from a trustworthy source.

Most participants receive information online, from social media, in the newspaper, in magazines and on TV. They also stated these channels as their preferred channels for learning about blockchain. Participants stressed the importance of trustworthy sources and can also see e-mails with a link to informational videos as an option as long as it comes from someone trustworthy.

Finally, it seems important not to overload potential users with information as this could create insecurity if they don't understand everything that is mentioned. In this sense a clear distinction of what is an important part of the basic concept and what is additional detail information could help avoid such an uncertainty. It is important to reassure them in the main concepts without confusing them with too many additional details. For this, it will be important to determine which information is essential and which can be considered an additional detail.

In general, a careful wording is very important for a clear understanding. Ambiguous, confusing wording should be avoided. Imagery and animation can support readers in following the content and grasp concepts easier. However especially then it is important to choose the wording in a way that it compliments the visuals and vice versa.

4.2 Expert Interviews

After gaining first insights through the analysis of the non-expert workshop, expert interviews were self carried out to further inform contents and design of the learning methods from the different perspective of professionals. As a user research method expert interviews are described by Flick [Fli18] as a semi-structured interview where the interviewees give information in their role as an expert, representing not only themselves as a person but a group to which their expert knowledge applies.

4.2.1 Research Interest and Aim of Interviews

The aim of the interviews was essentially to gain insights on what type of information of the blockchain technology should be conveyed to non-experts, preferrable on the example of peer-to-peer energy trading. This is linked to questions around how blockchain would integrate into peoples' lives in the future, what characteristics, advantages or threats are different from other common technologies and if there are any important aspects a typical user would benefit from knowing. Hence the semi-structured interview guideline focused around questions of how blockchain would integrate into peoples' lives, whether they would take notice of it, what could be important to know for non-experts, what type of experiences the experts previously had around the topic of informing about blockchain, how they perceived the users' knowledge and whether they have any personal insights or opinions on this matter. The rough question guideline which was then personalized in small extents for each expert can be found in the Appendix, see Figure 1. However, this served merely as a guideline and wasn't followed in all cases. Instead it was preferred to follow leads that came up during the conversations if they were relevant to the topic.

4.2.2 Interview Partners and their Relevance

Six experts were contacted and asked for an interview of which three replied and agreed. The aim was to find experts with either high knowledge of the blockchain technology or people who have worked in blockchain projects in various roles.

Expert 1, male and in his thirties, is working in product development handling project management in a local energy provider company. He has worked in various projects dealing with blockchain in the energy context in pilot, research as well as wholesale trading projects. He is considered a blockchain expert by the media. Several interviews of him talking about blockchain projects can be found online of which some of the quotes were referenced in the interview.

Expert 2, male and in his fifties, is coordinator for a data science group and senior scientist himself. Blockchain is a major focus of his group including in the energy area. They provide blockchain prototype development expertise meaning they consult, design and develop solutions using blockchain technologies. The group is also concerned with questions around where and when using a blockchain is a good solution for certain applications. He was interviewed to provide expertise from a technological perspective.

Expert 3, male and in his thirties, has a computer science background and is now working in an energy department of a scientific institution. He is currently part of a research project involving blockchain in the peer-to-peer energy trading. His role is to optimize energy usage of participating households.

The experts are all working within blockchain project contexts and have different sets of expertise ranging from managing blockchain projects, to high technological expertise of the blockchain technology, to having insights into a P2P energy trading project from a computer scientists perspective. They agreed to be interviewed and referenced in this work, however remain anonymous.

4.2.3 Setting and Procedure

The interviews were held in January 2019 and each took approximately 30 minutes. The interviews language was the interviewees respective native language which is German for Expert 1 and Expert 3 and English for Expert 2. This was preferred so that the interviewees could comfortably and fully express their expertise. The interviewers native language is German. Naturally this could mean that there were minor miscommunications or misunderstandings in the interview with Expert 2.

Expert 1 chose to be interviewed in a café close to his office as there were no meeting rooms available. Experts 2 and 3 were each interviewed in their offices respectively. In all the interviews the interviewee and interviewer sat across from each other vis-à-vis.

After greeting and thanking them for their time with a little treat, they were asked to sign a consent form. In the consent form they agreed to this interview being used for research purposes in this thesis as well as being audio taped, however remaining anonymous.

The audio recording device was placed on the table between interviewee and interviewer and turned on after the consent form was signed. In all interviews the audio tape was clearly audible and comprehensable, including the tape from the interview held in the café which is accompanied by background music.

4.2.4 Analysis

Firstly, the interviews were roughly transcribed and thereby listened to once again. From reading the transcriptions, quotes that are relevant for the research purposes were highlighted before summarizing the most important messages and statements for each interview in keywords. Finally, these messages were compared and thematically ordered to correlated themes.

4.2.5 Results

This section presents the themes that emerged from the thematic analysis of the interviews. They are represented in own words and partially underlined with direct quotes in order to keep the messages genuine to the interviewees. As two of three interviews were held in German language, these contents were translated to English.

Blockchain in peoples' lives

All three experts agreed that ideally the blockchain technology shouldn't be particularly visible to users. Expert 1 argued that blockchain shouldn't be in the focus of the application but rather the functionality should be in the spotlight. This is in accordance with the fact that blockchain is a backend technology and one of the main discussion points as part of RQ2 of this thesis.

Arguments against giving further information

The experts brought up various reasons that speak against particularly informing users on blockchain. However as the next theme shows, all of them also brought up reasons for why users should or even must be informed of certain properties of blockchains. Expert 1 argued, that users are in his experience not interested in the technologies being used in an application. He drew a comparison to Netflix where the wide majority of people doesn't know on which database infrastructure it works either. Another reason was brought up by Expert 2 who made a point that no one should be forced to disclose all technological choices as this is part of the valuable intellectual property of companies. Either every company would have to disclose such information or nobody. He doesn't see why blockchain would be different in this aspect. Finally, Expert 3 doesn't think users miss out on anything from not knowing technical details of blockchain.

Arguments in favor of giving further information

As already indicated above, each expert also brought up reasons why users should or must be informed of certain aspects of blockchains. Expert 1 and 3 both believe that it makes sense to relieve some skepticism and worries towards blockchains so that users could feel more comfortable with it. Expert 3 also reasoned in this regard that users could miss out on advantages such as saving money by not participating in e.g. a P2P energy trading project. It is further convenient to provide some quick information in an FAQ section to save on user support by not having to answer this to several people individually according to Expert 1. According to Expert 2 it should be communicated that there is increased transparency and a higher level of trust even if or especially because it might not be visible to users. Finally and perhaps most importantly, both Expert 2 and 3 brought up legal responsibilities regarding data protection and deletion of data. Expert 2 argued that *„[Users] should know what's happening with their personal data, that's not just. The ethical thing is now becoming a legal requirement as well."* linking to the General Data Protection Regulation (GDPR), right to be forgotten and the property of blockchains that data cannot be deleted in a traditional sense.

Information that must be conveyed

Expert 2 and 3 both believe that users need to be informed that records cannot be deleted on a blockchain, linking this to the GDPR. This is in accordance with the last argument from the previous theme. Furthermore, Expert 2 extends this to include the information that all data is replicated and shared among participants which could have implications on data protection and privacy, depending on the application possibly a legal requirement as well.

Information that can be conveyed additionally

Both Expert 1 and 3 believe that key characteristics such as that the technology is safe, forgery-proof, utilizes no intermediary or is immutable can be interesting factors to convey to users. However both think this should be kept simple and technical details should be kept to a minimum. Expert 1 reasons that instead interesting factors in relation to the project should be emphasized. Expert 3 thinks that possibly explaining the concepts of blocks and how they are chained together with hashes could serve to strengthen a sense of security in case there are doubts. He further brought up that not the lack of knowledge is a problem but rather the incorrect or incomplete knowledge. According to Expert 3 there are several myths from other applications in the finance area naming Bitcoin and its high transaction fees or high energy expenditure as an example. Such factors do not always apply which should be clarified and corrected according to the application. Finally, Expert 2 did not state specific information as he believes it is too early in development to recognize what information should be conveyed additionally to avoid misunderstandings.

How and where information should be conveyed

While Expert 2 expressed that informing should be implemented more fundamental than just in the introduction of an application, Expert 1 believes that a short text with a diagram and maybe a link to other resources in the FAQ section that can be found in the user interface is sufficient. Expert 3 envisions the information presented by the product provider for example in a web interface, an app or the project homepage with details for interested users. Another option would be a small accompanying digital or printed booklet that customers would receive together with the product. This booklet could include information on how to use the product as the main part up to a rough explanation of blockchain as a secondary part. According to Expert 3 this information should be presented way that is easily understandable for a layperson including only basic elements, leaving out details such as Proof of Work or Proof of Stake.

Experiences regarding blockchain knowledge

The experiences the experts mentioned were centered around the work in projects they are doing. All experts recalled situations where the familiarity with the blockchain technology varied substantially between the different project stakeholders. This lead to less productive work meetings, according to Expert 1. A similar experience was mentioned by Expert 3 recalling that in project meetings occasionally some *„myths“* around blockchain had to be resolved and clarified by blockchain developers to the colleagues without much prior blockchain knowledge. Expert 2 often sees companies wanting to use blockchains in their projects where they are often not best suited. A *„lengthy educational process“* is then necessary to explain properties of blockchains that are not ideal for their use case.

Personal experiences around explaining blockchain

Two experts also shared some personal experiences of conveying parts of the blockchain technology to people. Expert 2 recalled explaining by referring to the Bitcoin example as this is known by most people. Depending on their prior knowledge, background and level of interest he would explain hashes, chaining blocks together up until proof of works and including that there are different kinds of proofs suited for different applications. He says a full holistic explanation is difficult however explaining on a basic level without including too many details should be manageable. Expert 2 further noted that some participants from a workshop became skeptical when blockchain was explained on its own without putting it in context of an application. He therefore would recommend to emphasize the uses and valuable properties of blockchain for the users. Expert 3 found using sketching as support to explain basic concepts to family and friends helpful. He believes starting very easy and going into detail further along is best before eventually referring to other sources of information.

4.2.6 Summary and Conclusion

Three experts who all work with the blockchain technology, however in different roles were interviewed individually for 30 minutes each. In order to gain insights on what type of information should be conveyed to non-experts, the experts were asked questions around how blockchain would integrate into peoples' lives in the future and what properties or aspects a typical user needs to know or would benefit from knowing. The interviews were audio recorded so that they could be transcribed for a thematic analysis. In the following paragraphs, the contents of the themes that emerged from the analysis which were presented in subsection 4.2.5 are summed up. They represent the information that relates the most to the initial aims of the expert interviews which were to inform the contents and design of the learning methods for this thesis.

While the experts agreed that blockchain shouldn't be visible to end users and that the majority of users isn't interested in technical details, there were nevertheless arguments that speak in favor of informing users:

Most outstanding in the context of the GDPR it would in most applications be a legal responsibility to inform users that data is replicated and shared among participating nodes as well as that data cannot be deleted in a traditional sense from a blockchain. This relates to data protection, privacy and right to be forgotten.

Other arguments were to reduce skepticism and worries so that users could feel more comfortable using an application operating with blockchain. This should include blockchains' characteristics of claiming to be safe, forgery-proof, immutable, without intermediary while keeping the information simple with minimal technical details and instead emphasize use cases and interesting factors for the applications. Other elements that could be included is to demonstrate the concept of blocks and how they are chained together with hashes which could strengthen the sense of blockchain being safe.

Expert 3 talked about incorrect or incomplete knowledge being an issue, partly revolving around *„myths“* of blockchain as he called them which stem from applications from the financial sector such as Bitcoin being covered by the media a lot. He would make a point of illustrating that some properties, such as transaction costs or energy expenditure, vary depending on the applications and which mechanisms it uses.

A slightly different point of view was brought up by Expert 2 who pointed out that as blockchain shouldn't be visible to users, they also wouldn't notice the increased transparency and higher level of trust the technology offers. This information in combination with the information around the aspects related to the GDPR led to him arguing that informing users should be more fundamental than just in the introduction of an application.

Information should be kept short and simple, leaving out too many technical details. It could be presented in a separate section such as within FAQs, a web interface, homepage, or digital or printed booklet that comes with the product which were the examples named by the experts.

Blockchain technology should be put into context of applications, emphasizing its uses and valuable properties for the users. Sketching as well as examples can help giving non-experts an easier entry point into the contents. Particularly the example of Bitcoin was named twice as it's well-known. Further contents suggested to include are hashes and how they are used to chain blocks together up until proofs, however bringing up that there are different kinds of proofs which are suited for different applications. The last suggestion was to start easy and then go into further detail if users are still interested.

4.3 Derived Learnings and Requirements

The learnings from the combination of the expert interviews and the workshop with non-experts formed the basis for the contents and shape of the learning methods which are presented in chapter 5. They were collected and put into categories that give different kinds of indications on what the learning methods should look like. As the information was for the most part not very specific, they were not forced into formal requirements but rather used as guidelines in the design process. They were categorized into goals, contents and methods and are presented in bullet point style in order to keep an easy overview.

Goals

This theme describes the aims of what should be achieved with the learning methods as well as some indications of how the learning method should appear. Note that especially the points related to feelings are not meant to be achieved by manipulating people but rather by informing them.

- Inform people in an accessible way
- Explain buzzwords brought up by the media
- Reduce uncertainty
- Increase level of comfort and trust as a result of being better informed
- *„Recreate“* incomplete / incorrect information or believes, resolve incorrect myths

Contents

The following bullet points outline the information that the prototypes should contain. These contents were indicated by the experts and/or the non-experts in the workshop.

- Explain buzzwords brought up by the media
- Examples for applications and uses
- GDPR: how it is relevant for blockchains
  - Data replicated and shared on participating nodes
  - Data cannot be deleted
  - Data protection, privacy and right to be forgotten
- Concept of blocks and how they are chained together with hashes
- Characteristics: forgery-proof, immutable, without intermediary
- Convey the increased transparency and higher level of trust the technology offers
- Address common myths

Learning Methods

This section collects indications for what the learning methods or elements of learning methods should pay attention to. These requirements were mostly collected from the workshop and the feedback to the presented learning material. Note that imagery and text may be part of multiple learning methods such as for example a video or a brochure.

- Video
  - Favorite method of workshop participants

  - Level of detail and length should be balanced, not too fast to follow
  - Animations, voice-over and subtitles helpful

- Text
  - Carefully worded
  - Shouldn't be ambiguous
  - Easy understandable, lively and with examples
  - In combination with visuals
  - Wording should go well with imagery and compliment each other

- Imagery
  - Should be clear and as simple as possible
  - Used to keep focus on important aspects
  - Shouldn't be used to give more information
  - Not overloaded
  - Sketching could be used to give an easy entry point

These derived learnings provide both a guideline as well as several indications for details to pay attention to for the prototypes in this work. The contents give a rough guideline of the type of information they should contain. The learning method indications give indications as to how they should be presented, with which tools, techniques, and in which style. And finally, the goals comprise not only contents but also the effects the prototypes should have on people. These derived learnings are a in a way an affirmation of the reserach questions (see section 1.2) as they address the similar matters of learning effect, level of comfort and level of abstraction. The next chapter will describe which learning methods were chosen for the three prototypes and why.

CHAPTER 5

Concept & Design of Prototypes

Three prototypes of digital learning tools were conceptualized, designed and developed based on the results from the requirement analysis.

The goal was to find digital learning methods that would be as diverse as possible while being able to convey the same information in order to compare their effectiveness in a meaningful way in the user study. The information is, in large parts, conveyed using the same wording as well as imagery. By keeping the information as well as wording and imagery similar, the results of the user study will reflect the differences of the learning methods to a higher extent.

The chosen methods are an animated video with voice-over, a learning game for smartphones as well as a website. The video was chosen as a result of the feedback from the workshop where it was the learning method with the most positive reactions and comments. The game was chosen as a contrast, to see whether information could be conveyed in a light and playful way and because it has shown positive effects in literature. Finally, the website was chosen as a traditional basis to compare to. Therefore it is designed in a rather basic way with text and images.

In all of the learning tools the contents are divided into smaller portions of information with multiple-choice questions in between. They are meant to support the learning effect by reviewing information directly as well as keeping the learners active and attempting to create a less monotonous learning experience for them. These questions are kept the same in each of the methods so that, again, the results could be compared meaningfully in the user study.

The following sections will describe the addressed contents, rough storyline and multiple choice questions of the learning methods. These is kept the same or similar across the different learning methods for reasons mentioned above. Afterwards the three prototypes are presented in order of their development which was first the video, then the game and finally the website. For each prototype a brief description of the design and development process followed by images and details of the final prototype will be presented.

5.1 Content and Storyline

Before developing the learning methods it was necessary to decide and determine the contents that should be addressed and explained. While the workshop and expert interviews already gave some direction of what those contents should be they were not very specified nor did they give a storyline. This is why this phase was crucial before developing the learning prototypes.

The workshop showed that some participants already had prior knowledge to some extent however their information was incomplete or they did not remember everything. While this is true for these participants it is unclear which prior information the viewers already have and which is missing or needs to be reviewed. For this reason it was decided that the learning methods would assume that the audience does not have prior knowledge and start to explain from the very basics.

As listed in section 4.3 Derived Learnings and Requirements under 'Contents' some key points to address were already set. Further adhering to the found requirements, in particular to the pointers regarding the text and imagery, a guideline in form of a rough storyline was developed. This storyline or order of addressed contents was only slightly modified for each different learning method. The following list schematically depicts this order of information:

- Example of how blockchain could be used in the energy context
- Rough description of what a blockchain does, what it is used for and what characteristics it has without technical description
- Concept of blocks, what information is stored in blocks
- How blocks are chained together
- Brief explanation of hashes using metaphors
- What is an intermediary in the blockchain context, what do they do, how are intermediaries replaced and why
- Decentralization and three common consensus mechanisms: Proof of Work, Proof of Stake and Proof of Authority
- Data storage, replication and deletion
- Summary of the most important advantages and disadvantages

This information is explained in different ways according to the learning methods and serves as a guideline for the order of contents. Furthermore the energy context should be tied into the explanations. As mentioned earlier in this chapter, multiple choice questions were integrated into the learning methods which was another factor to consider for adapting this guideline to the learning methods.

5.2 Multiple Choice Questions

Seven multiple choice questions were added inbetween sections of the learning methods as an additional learning tool. The idea was to promote immediate repetition of contents directly after learning them in order to keep the learners more active rather than passively receiving information. These questions were kept the same with only minimal changes in wording across the three prototypes so that the study wouldn't be biased by this factor. The following lists these seven multiple choice questions with their corresponding answer options, the checked boxes represent the correct answers. Note that the questions and answers are highly simplified in both language and correctness to convey concepts and ideas and suit the simplified explanations for non-experts.

What is a hash?

☑ A hash is a checksum that encapsulates the contents of the block cryptographically.
☐ A hash is a 1:1 representation of the business transaction.
☐ A hash connects the blockchain to the business transaction.

How are blocks chained together?

☑ The hash of the respective previous block is contained in the new block.
☑ The hash of the respective previous block is included in the calculation of the new hash.
☐ There is a list in which the order of blocks is written down.

How does Proof of Work function?

☑ Due to the high amount of work necessary to calculate a hash, it is hard to manipulated them.
☐ Due to the high amount of work necessary to calculate a hash, it is hard to validate them.
☑ The required work can be compared to a difficult puzzle that is solvable through enough trial and error attempts.

How does Proof of Stake decide who writes the new block?

☐ It uses a randomized mechanism that selects purely at random.
☐ It uses a randomized mechanism that favors users that have high stakes in form of a lot of money in the network.
☑ It uses a randomized mechanism that favors users that have high stakes in form of lots of transactions within the network.

Who writes/verifies the blocks using Proof of Authority?

☐ Users with lots of experience who have been in the network for a long time.
☐ Users that have a lot of network money and thereby more authority and power over the network.
☑ Users whose authority and trustworthiness is proven.

What is the consensus mechanism? What is it used for?

☑ It serves to replace the central controlling intermediary.
☑ The consensus mechanism ensures that everybody has the same version of the blockchain saved in their local storage.
☑ It is a system in which every participant of the network equally reviews the validity of data in new blocks and votes for its acceptance/denial into the blockchain.

Can data be deleted from the blockchain?

☐ Yes, data can be deleted unproblematically like from any other database.
☑ No, as the data is cryptographically chained together. They can however be anonymized.
☐ Yes, after deleting the respective data from the blocks, the rest can be chained together freshly which is fairly unproblematically.

5.3 Animated Video with Voice-Over

Animated videos are a common form of digital learning and used across various areas. As the video was the learning method with the most positive feedback from the workshop they were chosen as one of the learning methods to be further investigated in a further developed prototype than the one used in the workshop. The video was developed first as this would allow to reuse wording as well as imagery in the subsequent learning prototypes.

5.3.1 Script

The script for the voice-over determined the contents and specific order of contents and was written based on the content guideline presented above. It furthermore considered the pointers described in section 4.3 Requirements for the text.

Other considered aspects were to address the viewers directly, use rhetorical questions, repeat contents in different words, explain words that could be unfamiliar and generally use simple language and wording. Also, an overview was given in the beginning and then used to come back to several times during the video. These techniques as well as many examples were integrated at various points during the script to make following and understanding easier and to keep the viewers attention.

As the user study was to be conducted with German speaking participants the script was written in German language. The following text is a translated excerpt from the script. It is taken from the first page of nearly four pages script text and is dealing with the second and third bullet point from the contents listed above in section 5.1. The full script can be found in German language in the Appendix 10.

> What is so special [about blockchain] you're wondering? The blockchain technology is forgery-proof, transparent and enables transactions directly from user to user, that is from peer to peer, without an intermediary as a controlling factor. That means, it enables a secure trustworthy data exchange for business transactions directly between participants of a network without the need for a controlling organization, like for example a bank or an energy provider. These properties arise from the special technical architecture of blockchains.
>
> The special technical architecture is composed of a combination of cryptographic concatenation, decentralization and a consensus mechanism. That is a lot all at once. Let's have a look at it from the ground up. Why is it called block-chain? The blocks are the form of storage in the computer. So a block is used to write information inside of it. The blocks are cryptographically chained together and build a secure source of information, a digital kind of ledger or register so to say, which is particularly suitable to be used for business transactions.
>
> For an energy transaction, a block would contain who sold how much of energy to whom, to which price and other details.
>
> In Bitcoin, the blocks store money transactions.

5.3.2 Tools and Procedure

After setting the contents and writing the script, the tools to create the video were chosen. As the video was meant to be a prototype that is relatively fast to produce the tools were chosen based on availability and ease of use. The video prototype was created with animated vector graphics using Adobe Animate [Adoa], Adobe Illustrator [Adob] and partly self-created graphics partly graphics from the free online platforms Flaticon [Fla] and Vecteezy [Vec]. The macOS video editing software iMovie [App] was used to cut the video and add the self-recorded audio. Finally the multiple choice questions were added with the free website building kit Wixsite [Wix].

Animation Software

It was quickly decided to use Adobe Animate [Adoa] (formerly Adobe Flash Professional) to create simple animated vector graphics that would help the audience follow the spoken explanations. Due to its easy handling, Adobe Animate enabled a fast creation of uncomplex animations which was ideal for the video prototype. The Adobe Animate environment is based on a timeline where vector graphics can be edited frame by frame using features that facilitate most uncomplex animations such as translation, scaling or rotation. The tool further allows to export the results for various platforms which can be used for games, apps, websites or videos.

Vector Graphics

The vector graphics that were animated in the video were partly self-created graphics and partly graphics from the free online platforms Flaticon [Fla] and Vecteezy [Vec]. A list of references of the artists that created the used vector graphics can be found in the Appendix 10. The creation of new graphics and editing of downloaded vector graphics was accomplished with Adobe Illustrator [Adob]. The desktop application Adobe Illustrator is a vector based graphics and drawing software that is used to create or edit vector graphics such as illustrations, logos, drawings, cartoons and artwork. Unlike pixel-based graphics, vector-based graphics can be arbitrarily scaled without loss of quality which makes them resolution-independent.

Audio and Cutting

The script for the voice-over was recorded with the Zoom H2n device in a quiet room. The explanations were self-spoken without a professional speaking background and therefore suitable for a prototype only. As mentioned above 5.3.1 the script was written in German language and therefore recorded in German language as well. The recorded audio was then added to the animated illustration video material using the macOS software iMovie [App]. iMovie is a video editing software that comes with the Apple operating system and is particularly easy to use for beginners.

Interactivity

Finally, as the last touch interactivity was added in the form of multiple choice questions. This was done using the free website building kit Wixsite [Wix]. The video was divided into eight pieces and the seven multiple choice questions (section 5.2) were added in between. These questions are the same that are also used within the game and website.

5.3.3 Video Prototype

The final video prototype that was used for the user study is an animated illustration video that is 12 minutes and 32 seconds long. It was attempted to keep it light-hearted, sketch-like and friendly while conveying a basic understanding of the blockchain technology. The illustrations were partly taken from online platforms and partly self-created. To facilitate following the explanations the illustrations were animated with simple tools such as translate, rotate and scale which allows to keep the viewers gaze and attention at the relevant parts of the screen for that moment. However attention was paid not to distract learners by moving too much at the same time or when it is not necessary. The script in German language, which was known to be the language of the user study, was self-spoken, recorded and cut to go along with the animations. Finally, seven multiple choice questions (section 5.2) were added in between sections of the video to keep learners active and instantly review information.

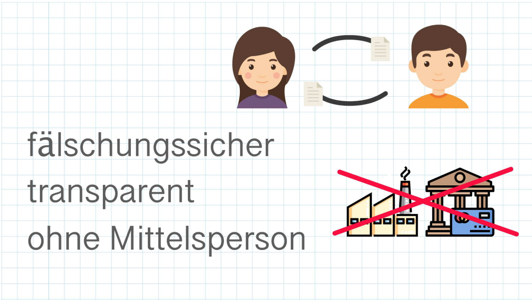
Figure 5.1 shows some screenshots to illustrate the sketch-like appearance of the video. The subfigures of Figure 5.1 are in order of appearance in the video prototype. Figure 5.1a depicts an overview of the characteristics forgery-proof, transparent and without middleperson that are then to be explained to the viewers. Figure 5.1b displays how hashes are first explained using the analogy of a checksum. It further continues to explain that it is instantly detectable if the checksums are incorrect for example when a malicious change occured which is signified by icons of a hacker, an alarm light and the anonymous mask. Hashes are later compared to and illustrated as a fingerprint of a block. As shown in Figure 5.1c the fingerprints are used to visualize the cryptographic chaining of blocks as a block contains the previous blocks' fingerprint which is included in the calculation of it's own fingerprint. Figure 5.1d illustrates the decentralization of blockchains and decentralized verification which is underlined by animations as well. The five persons represent participants of the blockchain network that each have the same copy of the dataset constituted by the chained blocks. The unattached blue block is the new block which was just verified and is to be appended to the blockchain. Figure 5.1e is a screenshot of the explanation that records can't truly be deleted on blockchains. It shows one possible way of handling a participants' resignation from the network which is to delete the assignation of the person's identity to the identifier (ID) within the network. Finally, Figure 5.1f shows the illustration of two advantages of blockchains for peer-to-peer energy trading which is its speed compared to customary practices and saving money by not going through an intermediary.
Lastly, Figure 5.7c shows what a multiple choice question looked like. The questions were integrated exactly the same way as they were for the website as in both cases Wixsite [Wix] was used to separate the information content from the questions.

5.4 Mobile Game

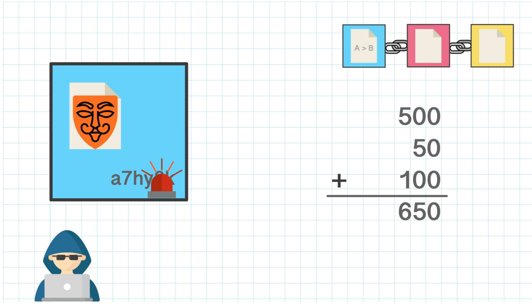
As elaborated in the literature in subsection 2.3.3, games have shown to provide many benefits for learning. As a rather new digital learning method it seemed interesting to include it in the comparison for this study as the learning contents are of digital nature as well. The development of this prototype took the longest out of the three prototypes: animated video, website and mobile game. This is partly due to the more extensive creative phase that was necessary to come up with playful ways for conveying the learning goals and partly due to the programming time needed.

5.4.1 Ideation

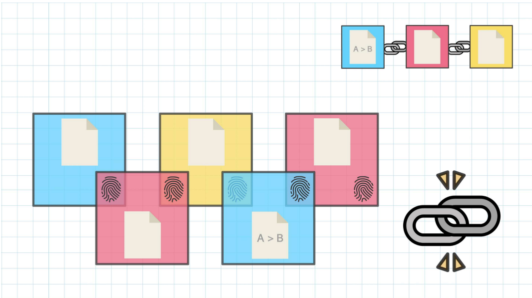
The phase of coming up with ideas for how a blockchain learning game could look like is termed the *Ideation* in this section. In this phase the type of game as well as its' structure and concept were determined.



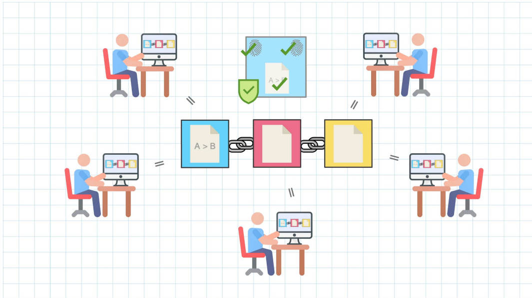
(a) Overview of important blockchain characteristics



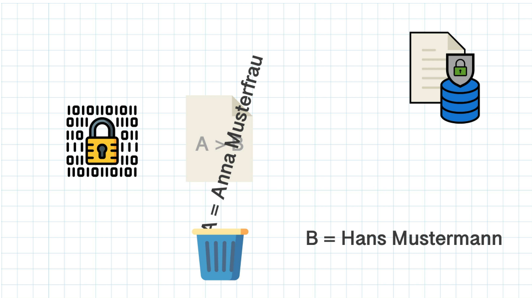
(b) Hashes explained as a checksum



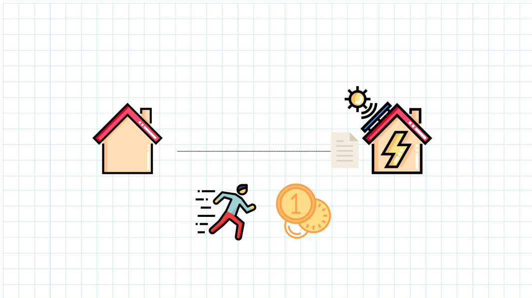
(c) Cryptographic chaining illustrated with fingerprints



(d) Decentralized verification of new blocks



(e) Possible handling of participants' resignation from the blockchain network



(f) Advantages of blockchains for peer-to-peer energy trading

Figure 5.1: Snapshots of the animated video prototype

However before starting the creative phase an overview of the contents that should be conveyed needed to be established or rather reviewed to be kept in mind while brainstorming ideas. This consisted of reviewing the contents and storyline established in 5.1 as well as reviewing the video. When analyzing the video, special attention was paid to how and with which analogies contents were explained, in which order and in which level of detail.

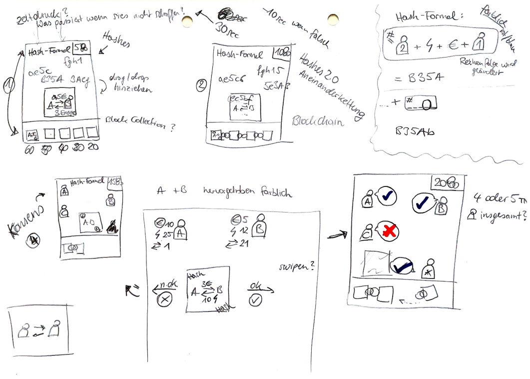
With this in mind a number of rough conceptual ideas were formed such as collaborative board games that would be digitalized, tangible puzzles made of 3D cubes with scannable QR-codes to give digital feedback as well as a number of mini games that each explain small portions of the learning goals. Finally, the decision fell on combining puzzle type mini games as levels to form partial explanations that build up on each other. This approach would also allow the use of the already established multiple choice questions in section 5.2 as well as achieving a similarity in learning style of learning small portions that are directly reviewed through the questions.

5.4.2 Sketching

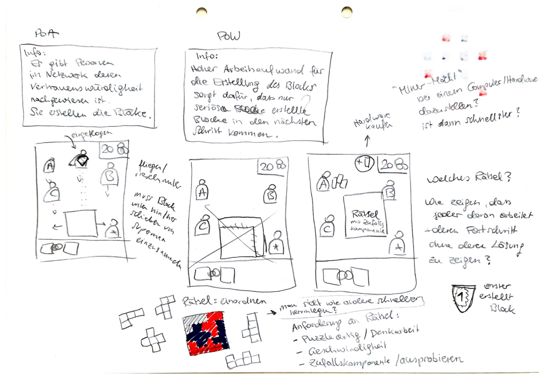
As described in chapter 3 sketching as a design technique is especially suited to give shape to ideas while remaining flexible. Sketching the ideas from the previous steps helped to communicate the mini games better and to figure out details that were not as visible before when the ideas were merely brainstormed and written down in words.

In this way all the mini games were first designed before developing them which not only accelerated this process but also simplified it as the interactions and necessary components were clear. The design included not only visual elements such as layout and graphical elements but also interactions and game elements. As the sketching and development was done by the same person within a rather short period of time, notes were only written down roughly which makes the sketches harder to understand for non-involved people. The process was to sketch ideas, sometimes several times, discuss and revise until the result was satisfactory.

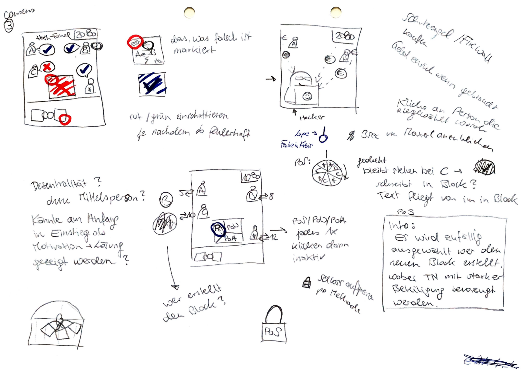
In Figure 5.2, a selection of the sketches used for the design of the mobile game are displayed. They are a collection of ideas that were put down on paper to communicate and further shape them. Sketching them out helped to realize which details were missing or where there are inconsistencies. Note that the ideas are ways for communicating basic ideas around blockchain technology in a simplified and playful way that are in no way complete representations of the technology. Figure 5.2a shows ideas of a simplified formula (in the top right corner) that should convey how hashes are calculated and how this formula could be used in a mini game under time pressure. The bottom half sketches are focused on interactions to verify new blocks and signaling consensus. Figure 5.2b displays parts of the ideation for using puzzles to let players get a feel for what proof of work means. On the left side is the sketched out idea for catching the 'superhero' that represents the authority capable of verifying new blocks to convey the concept of Proof of Authority. In Figure 5.2c more sketches around decentralization, consensus and



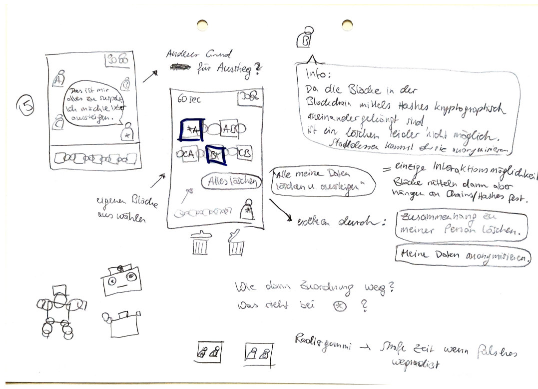
(a) Collecting ideas to convey hashes, cryptographic chaining and verification



(b) Outlined ideas to playfully explain Proof of Authority and Proof of Work



(c) Sketches for decentralized verification, a hacker as game element and a number of notes on game play



(d) Drafting simplified ways to convey that transactions can't truly be deleted on blockchains

Figure 5.2: Sketches to shape ideas for mobile game

playfully conveying its purpose building onto sketches from Figure 5.2a are shown. It further includes sketches for a navigation element used to navigate between the three options for the mini games around Proof of Work, Proof of Authority and Proof of Stake. Finally the sketches in Figure 5.2d are centered around conveying concepts of deleting data on a blockchain or rather how they can't be fully deleted.

The sketches were further used as guidelines to develop the mobile game. The final design of the mini games will be described in subsection 5.4.4 along with images of the developed prototype.

5.4.3 Tools and Procedure

As the ideation and sketching defined the requirements and necessary features for the development environment, the tools could be chosen. As with the video, they were chosen based on availability and ease of use as the prototype should be produced within a short amount of time. Wording as well as graphics were reused from the animated video, some were adapted or created new using the same tools and sources (see subsection 5.3.2). The game engine Godot [God] was chosen to develop the game and export it for Android devices. It was tested on a Google Nexus 5 smartphone as well as on other private smartphones in addition.

Game Engine

In order to develop the mobile game quickly and efficiently it was decided to use a game engine to facilitate rendering of graphics and collision detection. Physics were used as well for the first two mini games but however the games could have been realized without this element of bounciness. Several game engines were considered such as Unity [Uni], Corona [Cor] and Construct 3 [3] before opting for Godot [God]. The decision was based on pricing, ease of use, amount of features, exporting options, degree of freedom in development, and documentation, available tutorials and forum discussions of common issues. Godot [God] is a free and open-source game engine with a scene-based tree architecture. It allows to develop 2D as well as 3D games using a graphical editor as well as scripting. Godot uses its own scripting language GDScript which is similar to Python however optimized for the engine. Moreover it has an integrated animation system allowing to manipulate various attributes of the scene tree through keyframes at runtime. This particular feature was used heavily for this prototype. Finally Godot allows to develop on and deploy to multiple platforms which allowed to develop the game on a macOS laptop and deploy to an Android smartphone. This came convenient as the Adobe Creative Cloud was available on a macOS laptop. That way graphics could be created and edited on the same device that was used to develop.

5.4.4 Mobile Game Prototype

The mobile game is divided into five levels that successively build on each other for conveying basic blockchain concepts. One of these levels is further divided into three parts which can be played in any order as they depict different ways of verifying new blocks: Proof of Work, Proof of Authority and Proof of Stake. Each of the mini games first provides theoretical information on the blockchain concepts that it represents as well as tutorial information on what the task of the player is in the game. All mini games are based on a time limit as additional difficulty and fun element however if the time is up the player can simply try again without having to redo previous levels. After each mini game a multiple choice question (see section 5.2) is presented which are the same as in the other learning methods. In this section the mini games will be briefly described alongside screenshots of the prototype which was used for the user study.

Level 1 & 2

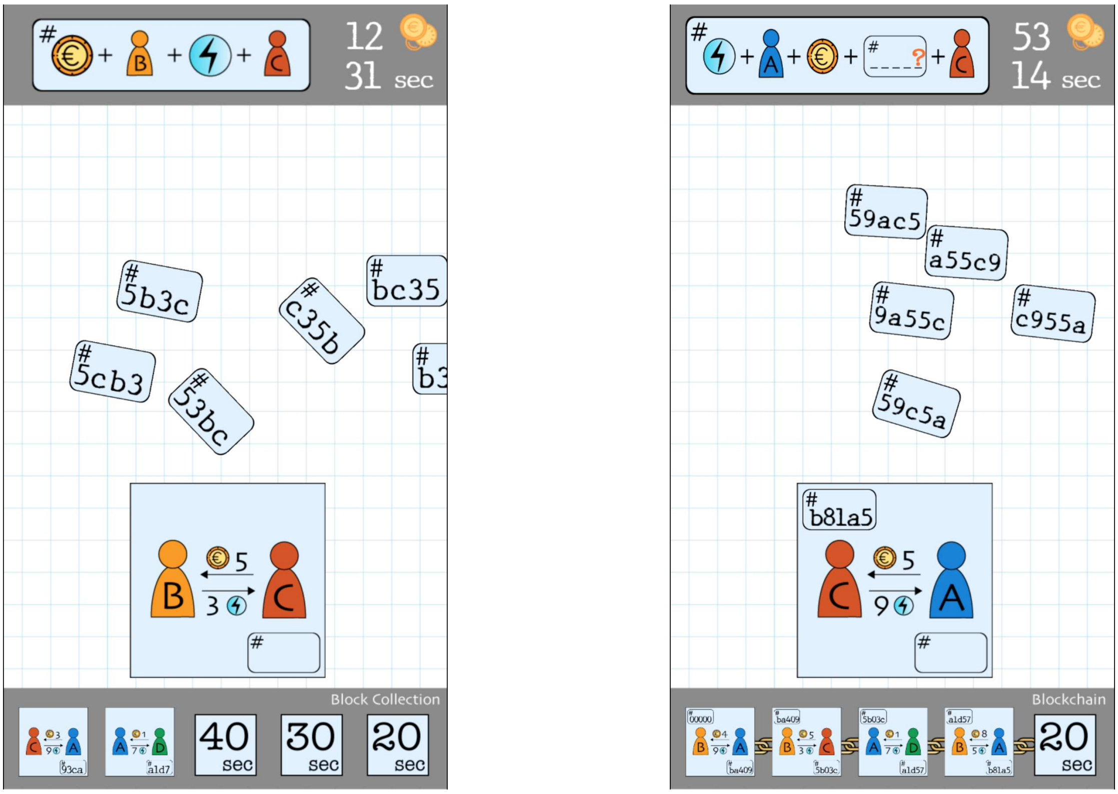
The first two levels look quite similar however the second level builds on the first and is more difficult. The idea was to first convey what hashes are and then further use them to chain blocks together.

Figure 5.3a shows the first level of the mobile game in which the task is to find the correct hashes which are represented in a very simplified way. The big blue square in the bottom half center of the screen shows the current block for which the hash needs to be found. The block shows a transaction between actor B and C where B is selling 3 units of energy for 5 coins to C. Smaller rectangles with different hashes are flying around above this block out of which the correct hash needs to be identified by the player and via drag & drop put into the block. The gray bar on the top shows the collected coins and the remaining seconds on the right and the hash formula on the left. The hash formula shows the order in which the information from the block is put together into the hash which is *5b3c* in this example. The formula changes for each block so that the player wouldn't simply remember it by heart. Finally once the player successfully picked the correct hash, the block will be moved into the *Block Collection* on the bottom. This has to be achieved five times within a decreasing time limit for each block as shown in the bottom bar.

Level two is quite similar to the first level in that the task and layout is the same as displayed in the screenshot in Figure 5.3b. However this time the hash formula includes a part of the hash of the previous block. This previous hash is shown in the top left corner of the current block of which the hash is sought. In this example the hash formula signifies to include the fifth position (indicated by the red question mark) of the previous hash at the fourth position of the new hash. The correct hash is *9a55c* in the displayed example. Furthermore the completed blocks are not put into the *Block Collection* displayed at the bottom bar but into the *Blockchain* as they are now chained together by including the previous hash in the calculation of the new hash. This is also illustrated by chain symbols between the blocks in the *Blockchain*. This concept of collecting completed blocks in a *Blockchain* is kept throughout the following levels.

Level 3

The third level of the game consists of three parts. They were put into one level with a choice of order for the player to point out that they are independent of each other and yet deal with the same matter: writing of new blocks and the trusted validity & verification of new blocks. The information text explains how this is relevant for blockchains while the games simplified the matter into which actor writes the next new block. Figure 5.4a shows the start of level three where players are given the choice of which type of proof they want to start with. After completing their first choice they can choose between the remaining two until they have completed all three options. In this level, each of the three mini games shows an information text beforehand and asks a multiple choice question afterwards. Furthermore, as all three mini games deal with writing the next new block,



(a) Level 1: Hashes

(b) Level 2: Chaining

Figure 5.3: Screenshots from Levels 1 & 2 of the mobile game dealing with hashes and chaining of blocks using hashes

the top gray bar is used to show what transaction the new block will contain in words as shown in the other subfigures of 5.4. However this information is not relevant to solve the tasks for the mini games.

The necessary effort under time pressure of Proof of Work is portrayed by a mini puzzle as depicted in Figure 5.4b. The task of the puzzle is to bring each of the four colors next to each other either vertically or horizontally by switching the colors of neighboring tiles. This is a somewhat tedious task as not much logical thinking is required once the task was understood. However it simply takes some time to complete which has similarity to finding the *"nonce"* for hashes as described in section 2.1.2. Additional similarity is achieved with time pressure by simulating other actors attempting the same task. The actor or player who is fastest in achieving all four colors next to each other in rows or columns can write the next new block and receives coins. As this is however a game and not reality, the player is shown how many seconds are remaining until an actor solves the puzzle which gives feedback and avoids frustration of random time limits. As in previous mini games, the completed blocks are collected in the *Blockchain* on the bottom bar and coins are rewarded.

Figure 5.4c shows how randomness is illustrated for the Proof of Stake mechanism. The player simply turns a fortune wheel and the result color is the color of the actor who writes the new block. The colors on the fortune wheel representing the actors are not distributed evenly but according to the number of transactions each of the actors have participated in. This represents the probability being higher based on participation in the network. It was decided not to use coins to represent this probability in the game to avoid the confusion that only people with lots of money would write blocks and would therefore be able to manipulate the blockchain. To make this somewhat playful the player is given three seconds to click on the actor that was chosen by the fortune wheel.

To illustrate Proof of Authority, the authority is embodied by an actor with a superhero cape and letter sign as can be seen in Figure 5.4d. The player's task is to move the new unwritten block sideways so that it is only touched by the superhero actor. The new block is then written by the superhero actor as intended, however the player still receives coins as reward.

Level 4

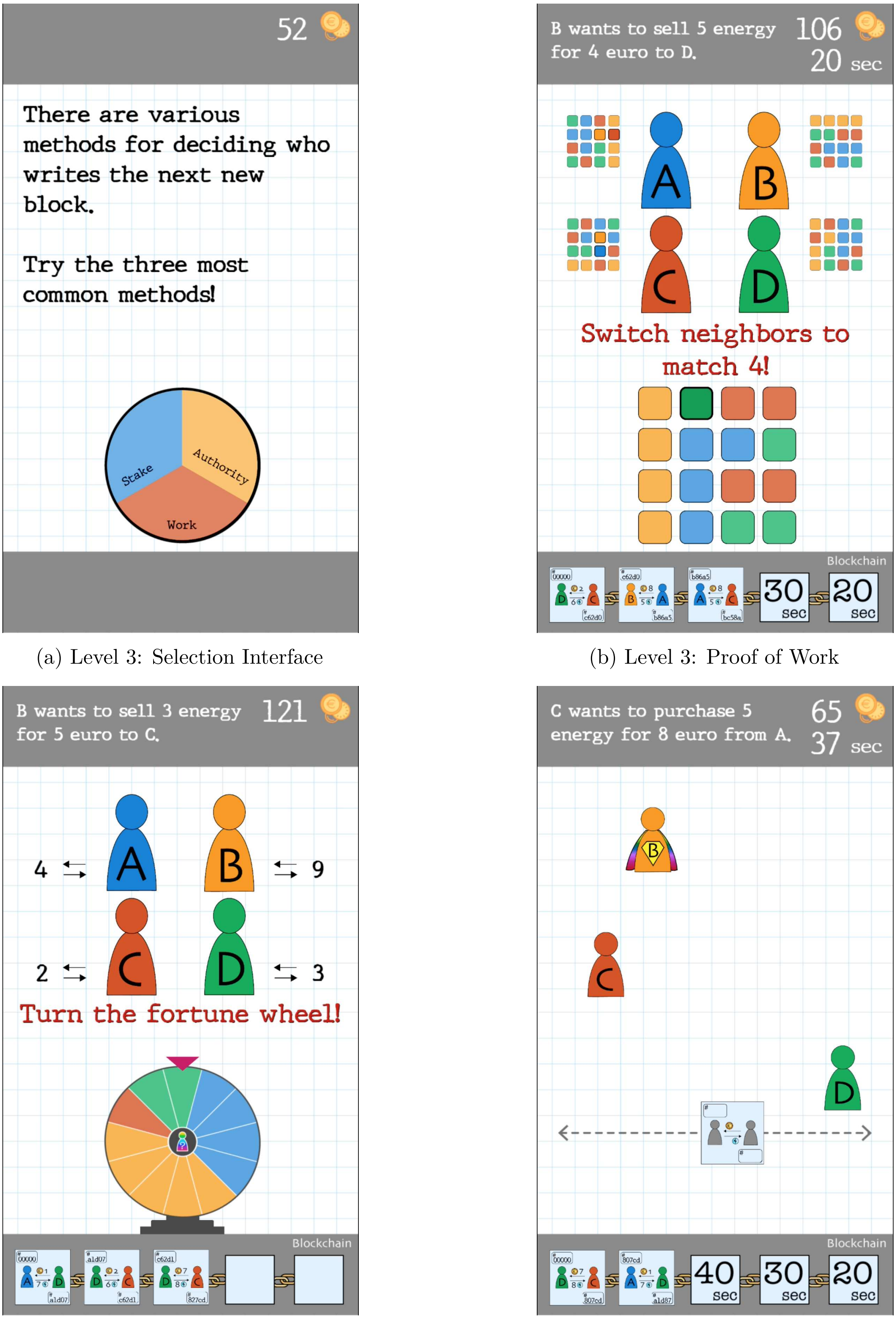
The fourth level deals with the consensus mechanism for accepting new blocks into the blockchain. For this, the player and the actors give a vote for a specific new block of whether it is valid or not. Depending on the result and the actual validity of the block, different outcomes take place. If the block is invalid but voted as valid a hacker steals money from the actors. If the block is valid and voted as valid it is added to the blockchain. If a valid block is voted as invalid it is not added and discarded, meaning the player does not advance nor get coins. The player recognizes valid blocks by checking their hashes and whether the actors have enough money or energy available. In the example in Figure 5.5a the new hash is incorrect, it should be *ab25c*.

Level 5

The last level serves to convey that deleting data from a blockchain is not possible in the conventional way as the hashes chain the blocks together cryptographically. Instead, an alternative option is shown in which the actors are anonymized. This information as well as the game task are explained before starting the mini game with a screen as pictured in 5.5b. The players task is to use the eraser via drag & drop to erase themselves from the blocks. The rainbow colored actors represent one's own actor and are to be anonymized into gray actors as shown in the bottom left block. As with the other levels, a time limit is given and a multiple choice question is asked after completing five blocks. As after this level the game is finished, a point score and coin score are presented afterwards.

Playful Elements

In order to achieve a more playful feel next to the learning components, some animated elements were included in the prototype. They serve both as information and feedback



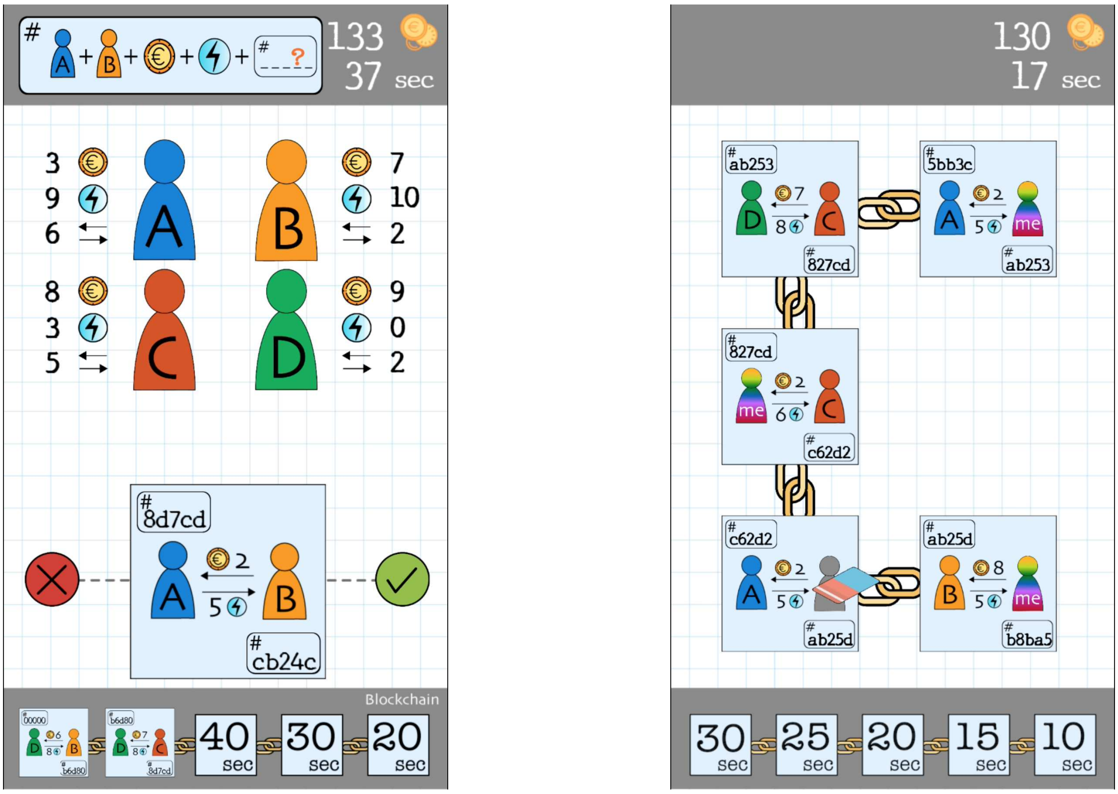
(a) Level 3: Selection Interface

(b) Level 3: Proof of Work

(c) Level 3: Proof of Stake

(d) Level 3: Proof of Authority

Figure 5.4: Screenshots from Level 3 of the mobile game dealing with the different types of verification for new blocks: Proof of Work, Proof of Stake and Proof of Authority



(a) Level 4: Consensus Mechanism

(b) Level 5: Data Deletion

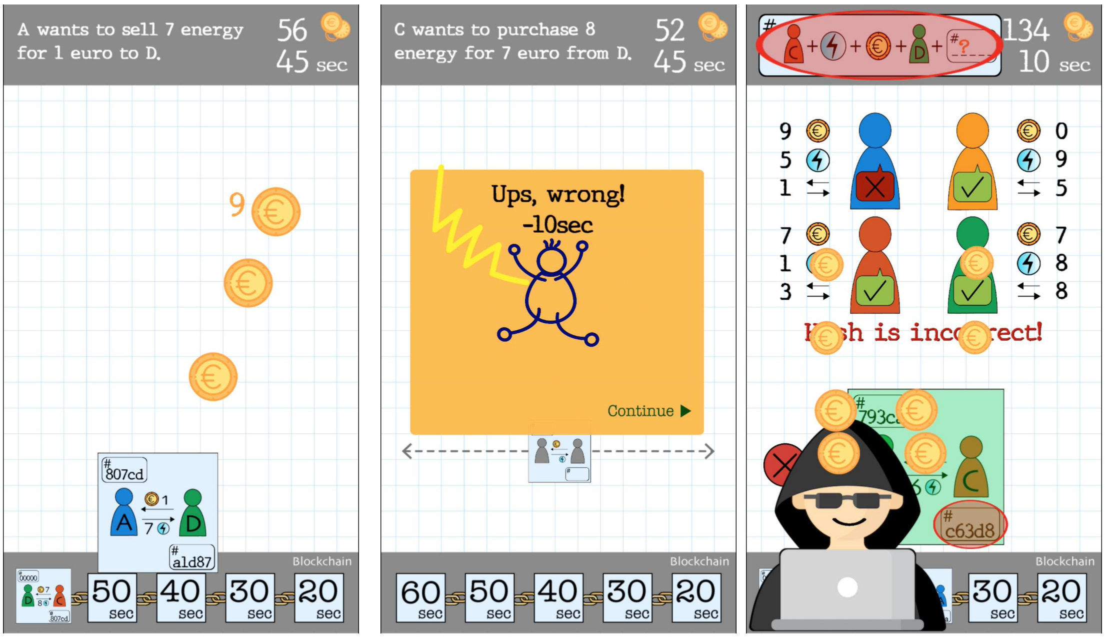
Figure 5.5: Screenshots from Levels 4 & 5 of the mobile game dealing with the consensus mechanism and data deletion

as well as as not so serious playful elements. Figure 5.6 shows three examples of such animated elements in form of screenshots.

Rewards are given to the player in form of coins that fly to the coin counter on the top right corner as shown in a screenshot in Figure 5.6a. Adding the animated flying coins rather than just increasing the coin counter steers the players attention to the coins and finally the coin counter so that the player recognizes the reward rather than going unnoticed.

The players' mistakes are shown in form of a short message *"Ups, wrong!"* as well as the consequence *"-10sec"* and a stick person that is given a small electric shock. The electrocution is animated with a simple lightening and a stick person that jumps with uncontrolled arms and legs as shown in Figure 5.6b.

The last example in Figure 5.6c shows a hacker's attack which is found in the fourth level. When the new block is incorrectly voted as valid, a hacker appears and attacks the network. This is animated with an illustration of a hacker flying into the screen and stealing money which flies from the coin counters to the hackers laptop. While the



(a) Money Reward (b) Mistake Electric Shock (c) Hacker Attack

Figure 5.6: Screenshots from animated elements that give the mobile game a playful component such as coins that are flying to counter as reward, an animated stick person that gets a small electric shock when there was a mistake or a hacker that steals money after an incorrect vote.

illustration is not meant to be scary, this element still illustrates the potential effects and consequences of such mistakes to the player.

5.5 Website

The third learning method that was developed is a website. The website was chosen as a base to compare with as it represents the digital version of the established learning materials of text combined with images. After developing both the video and the game, the majority of the text and images or illustrations were already created. These materials were reused for the website which not only made the development fast but also serves to ensure the content is the same over the different learning methods in order to compare their learning effect in the user study.

5.5.1 Tools and Procedure

As in the other learning methods, the goal was to create a prototype that contains the same information and is fast to develop. For this reason the free website building kit Wixsite [Wix] was used. The website should represent the established learning materials of text and images and was therefore kept simple in design without other types of materials such as audio, video or interactivity other than the multiple choice questions. As already mentioned, the contents of the website which are text, images and multiple choice questions were mainly reused materials from the video and game and adapted to fit the new presentation method.

Website Building Kit

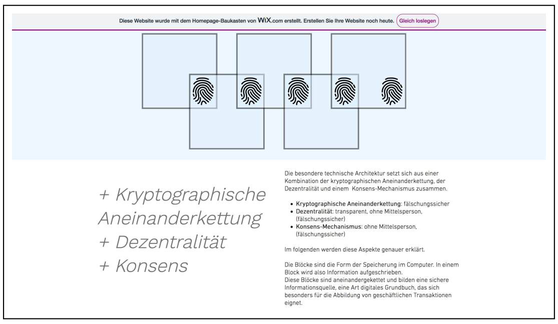
The website was built with the free online HTML5 website building kit *Wixsite* [Wix]. Wixsite allows to create websites by dragging & dropping elements into the preview. The tool offers many pre-built elements for free, however many elements that are desired for commercial use must be paid such as removing advertisements, using one's own domain, more data storage etc. The prototype for this work was built with only free elements using text, image, colored bars to separate sections, buttons and a multiple choice question elements.

5.5.2 Website Prototype

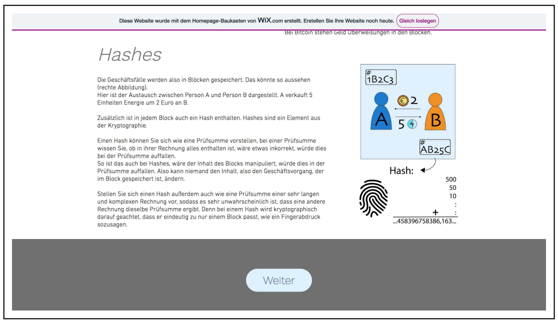
The website prototype as a learning method uses text and images to explain blockchain concepts. The same multiple choice questions (see section 5.2) as in the other two prototypes are used to add interactivity and directly review contents. A majority of the explanations as well as graphics such as icons and illustrations are reused from the video or the game. This has the effect that covered contents will be as similar as possible. As the user study was to be conducted with German speaking participants, the website was developed in German language.

Figure 5.7 gives an insight into what the prototype looks like. The first Figure 5.7a shows a section from the beginning of the information presentation. After an example of where blockchains are used, an overview of the technical components that are combined in the blockchain technology is given. The image on the top is a reused image from the animated video that was adjusted to fit the color scheme of the website.

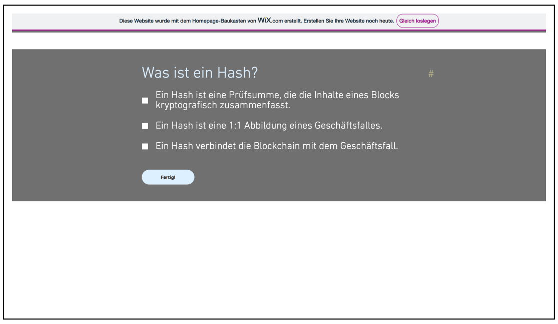
In Figure 5.7b the explanation of hashes is displayed. In this example, there is more text and a smaller image that was adapted from the blocks that are used in the game and the checksum analogy from the animated video. It further displays the "*Continue*" button which leads to the multiple choice question shown in Figure 5.7c. The multiple choice questions were separated from the content to avoid biases between the methods in the user study as they were separated in the mobile game for space and simplicity reasons. Finally, Figure 5.7d shows the explanation of decentralization using an image from the animated video.



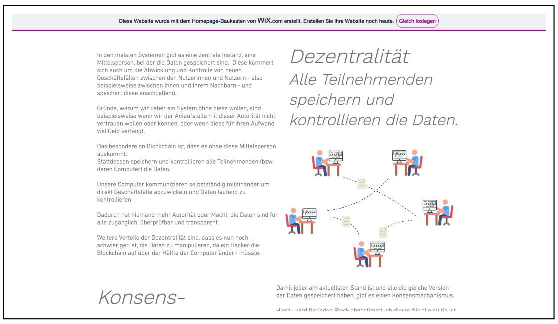
(a) Overview of Concepts



(b) Hash Explanation



(c) Multiple Choice Question on Hashes



(d) Decentralization Explanation

Figure 5.7: Screenshots from the website prototype showing the overview of concepts that will be explained in more detail, explanation of hashes and decentralization and a multiple choice question in German language.

CHAPTER 6

User Study

A user study with a qualitative and quantitative methods approach was conducted to evaluate and compare the three developed learning prototypes. The participants were asked to test one prototype in full and the remaining two in a shortened version. They were observed and encouraged to ask questions and give feedback. Pre- and post-tests were used to measure the learning effect and effects on subjective level of comfort. Furthermore the different forms of presentation of the same content were evaluated in the post-test to gain insights on which form is preferable and which level of abstraction is more appropriate. A semi-structured interview formed the end of each session. These approaches were chosen to create both qualitative and quantitative data in order to answer the research questions presented in section 1.2.

6.0.1 Study Design

The aim of the study was to answer the research questions (see section 1.2) by both evaluating each method on its own as well as to compare them in the aspects that are relevant in the research questions. In order to achieve this within a reasonable time frame of less than two hours, it was necessary to accept compromises. Audio recordings, screen captures and notes were used to capture qualitative data such as the interview, verbal statements, think aloud quotes or usage behaviour during the mobile game. Furthermore, the length of engagement with each prototype was noted in minutes.

Pre- and Post-Tests

Pre- and post-tests were used to measure participants' knowledge before and after using the learning prototypes as well as to capture some of their mindset and attitude towards the blockchain technology. The pre- and post-tests were designed as printed questionnaires using mainly multiple choice questions and some open questions. The full versions of the pre-test and the post-test can be found in German language in the Appendix, see Figure 2 and Figure 3.

The pre-test consisted of three parts. The first part collected some demographic information such as age, gender, education as well as information on previous experiences with blockchain and learning methods. This was to provide some context information to potentially be able to explain correlations or outliers in the analysis. The second part was a multiple choice section that tested participants' momentary knowledge of blockchain. It was decided to use multiple choice questions for this part so that the results could be directly compared to the post-test which would include the same multiple choice questions again. Finally, the third part was meant to capture participants' impression of the blockchain technology using selected bipolar pairs of the established User Experience Questionnaire by Laugwitz et al [LHS08].

The post-test consisted of three parts as well. Two parts were the same or very similar to the knowledge and impression parts of the pre-test which would allow to compare the results in the analysis. The first part are the multiple choice questions on the blockchain knowledge which are the same as from the pre-test. They were given to the participants directly after using the first prototype so that it would be possible to differentiate which method participants learned from the most. The second and third part were given to the participants after going through the other two methods in shortened versions (process described below). The second part used images to show different levels of abstraction. Each of the five questions focused on one partial concept of blockchain and showed different ways to explain or illustrate that same concept which have been used across the three prototypes. Participants were then asked which way of explaining they preferred and helped them to understand best. Finally, the third part on participants' impression included the same pairs of adjectives as in the pre-test and in addition questions on how their impression changed on a scale of one to five.

Prototype Testing

One of the goals for the user study was to achieve that each prototype would be evaluated on its' own as well as a comparison of the prototypes to learn about preferences. However in order to achieve a reasonable time frame of less than two hours a compromise was necessary.

It was decided that each participant would test only one prototype in full and the remaining two prototypes in shortened versions. Note that the first part of the post-test which tested the knowledge on blockchain technology was completed before showing the remaining two prototypes. This way the differences in knowledge would be caused by the first and full prototype only. The remaining prototypes were shown to be able to ask the participants about their preferences on learning methods and levels of abstraction. However, as mentioned, as a compromise the remaining two prototypes were shown in shortened versions for time reasons. The total time limit was set to ensure that participants would still be able to concentrate and digest information. It turned out, that none of the sessions needed to be interrupted in order to ensure a maximum of two hours of duration. The participants were given as much time as they needed to test the prototypes in full. They could rewatch, reread or redo sections as often as they wanted. From shortest to longest, participants took for the website prototype between 9 and 21 minutes (mean (M) = 12.6, standard deviation (SD) = 4.2), for the video prototype between 15 and 25 minutes (M = 17.2, SD = 2.3) and for the game prototype between 17 and 42 minutes (M = 27.6, SD = 7.95).

For the shortened versions, at least half of the sections were skipped. For the selection of sections, attention was paid to still provide a genuine experience of the prototype as well as to include different levels of abstraction so that participants could recall them and compare in the post-test. Especially for the mobile game, this meant that the first level had to be included as otherwise participants would be overwhelmed by too many new game elements. The shortened versions however still included the multiple choice questions after each selected section respectively.

The orders in which the prototypes were tested were evenly distributed. This means that each prototype was the same amount of times the first, second or third prototype to be tested where the second and third mean that the shortened version was used. This also ensured that each prototype was tested in full the same amount of times so that the same sample size to measure the learning effect of each learning method is achieved.

Semi-Structured Interview

A semi-structured qualitative interview was conducted to conclude the session. Essentially the interview focused on the same themes as the pre- and post-test however due to the verbal nature, information that wasn't covered in the questionnaires could be gathered. The interview started around the theme of general impressions of blockchain, what participants thought before the session versus now, what they like or dislike about the technology. Then, participants were asked about their prototype preferences: a ranking which ones they liked best and why, which ones they think has the best learning effect, which ones they prefer and for which purposes. Afterwards, they were asked about positive and negative aspects as well as where they see potential for improvements for each of the learning prototypes in the order of which they tested them. Finally, they were asked whether they remember any particular explanation that was easy or difficult for them to understand and whether there were explanations that were particularly confusing of helpful and why. Feedback about their experience during the user study formed the conclusion of the session. The interview guideline can be found in German language in the Appendix in Figure 4.

6.0.2 Procedure

The time schedule was carefully planned to ensure that the order of the study elements are correct. This was especially important for the handling of the pre- and post-test on the participants' knowledge a deviation would cause a significant bias. A pilot study was conducted to test this procedure and whether it adhered to the time limit. Furthermore it served to test the pre- and post-test, interview guideline and whether the shortened versions were well chosen. The participant was female, 24 years old, holds a Bachelors degree in occupational therapy and was currently studying Health Assisting Engineering where they have briefly mentioned blockchain technology. This makes her somewhat similar to the participants from the user study in terms of age, previous knowledge and basic interest in technology. To consider the worst case scenario for the time limit, the mobile game was tested in full as this prototype would potentially take the longest to go through. After the pilot study, only minor adjustments were undertaken such as the order of multiple choice options. The procedure was defined as follows.

- ▷ Welcoming
- ▷ Explain procedure and background of this user study
- ▷ Hand and explain consent form
- ▷ Start audio recording
- ▷ Pre-test questionnaire
- ▷ Experience first prototype in full - start/end screen capture before/afterwards
- ▷ Post-test part 1: blockchain knowledge questions
- ▷ Offer a 10 minute break
- ▷ Experience second and third prototypes in shortened versions
- ▷ Post-test part 2 & 3: abstractions and impressions
- ▷ Semi-structured interview
- ▷ Thank you and Good Bye

Following this procedure, the sessions took approximately 90-120 minutes with most of the sessions further on the 90 minute end.

6.0.3 Participants

The user study was conducted with 30 participants. This number of participants was chosen so that each of the three prototypes are tested in full by 10 participants. The participants were recruited from within a university lecture held at the Faculty of Computer Science at University of Vienna which was in the curriculum for the bachelors degree in computer science allocated in the fourth semester. This way the group was homogenous in that the participants are interested in technology, roughly similar age however not necessarily familiar with technological blockchain concepts as this is not part of the earlier semester lectures. The participation in the user study was a way of earning bonus points for students of this lecture. However students were given those bonus points upon arrival at their time slot, emphasizing that they are for their participation, regardless of their performance or stated opinions.

Participants were between 20 and 36 years old, with an average of 24 years and a mean of 23 years. 21 participants stated male to be their gender, 9 female. This gender distribution could be considered a limitation as this makes 70% male and 30% female

Figure 6.1: Setting of the user study: a neutral room with a desk and two chairs by a large window.

rather than a half-half distribution. From the 30 participants, as their highest completed form of education, 3 had previously completed a master's degree, 3 a bachelor's degree and the remaining 24 the "Matura" which is the Austrian diploma for completing the final exam of high school.

Participants were asked to indicate their previous knowledge on blockchain on a scale of 1 = beginner, little knowledge to 5 = expert. 20 participants marked to be beginners, 8 participants picked 2 of 5, and 2 participants picked the middle number 3 of 5. This makes an average of 1,4 on the Likert scale.

6.0.4 Setting

For the setting, a neutral and calm room that was located at the university and therefore convenient for the students was chosen. As pictured in Figure 6.1, the ground-level room has a big window with street view and a long desk oriented to look outside this window. On the table were monitors with keyboards and a mouse which were not used. The window blinds were half closed so that participants wouldn't feel observed by pedestrians outside. Otherwise the room was empty besides storage shelves.

The participants and the study conductor were sitting next to each other by the long desk. The sessions were audio recorded with the device positioned between the two people. A MacBook Pro with a 15 inch Retina display was used to show the prototypes of the website and the animated video. The same Nexus 5 smartphone that was used for development of the mobile game was used in the study to show the mobile game prototype.

Water was provided to the participants. They were also told at the beginning and reminded about half way through the session that they could take a break or use the bathroom at any time.

CHAPTER 7

Results

A lot of data was collected from the user study described in chapter 6. This data allows for many different ways to be digitalized and analyzed. To remain within the scope of this work, it was analysed with a focus on the research questions (see section 1.2) rather than attempt a holistic approach. For each of the research questions, quantitative as well as qualitative data was collected and analyzed and will be presented in this order.

For quantitative results, the data from the pre- and post-tests was first digitalized in an Excel spreadsheet before creating overview visualizations with respects to the research questions as presented and explained below. There could be many other interesting results drawn from this data such as correlations from the learning method preferences to the learning effect with the tested prototype, analyzing which exact answer options were crossed more/less often before and after the intervention and for which learning method which would allow to analyze each method on a deeper level.

The qualitative data was mainly collected from the notes of the semi-structured interviews that were held at the end of each session. Notes form relevant interview questions were collected for each of the research questions. These were then analyzed to find themes of statements that give insights to the corresponding research question. As with the quantitative results, the collected data could be analyzed in many different directions as well. The methodological approach of the thematic analysis is described in subsection 3.0.5.

7.1 Learning Effect

The first research question is:

> **RQ1:** Which methods have the highest learning effect for familiarizing non-expert users with blockchain technologies for peer-to-peer energy sharing and trading?

Both quantitative and qualitative data was collected and analyzed to find insights to this first research question. They will be presented in this order before comparing and discussing results.

Quantitative Results

In order to evaluate the learning effect, the results of the knowledge questions from the pre- and post-tests were compared and grouped by the learning methods that were tested in full. This means, that three such comparisons were undertaken, one for each prototype with the ten participants that tested the respective prototype in the full version. This makes for the intended quantitative data that would allow to compare the learning effects of the prototypes.

The multiple choice questions of the knowledge section were graded with one point for each answer that was correctly crossed or correctly left blank. As each question has three answer choices, this results in up to three points per question. These points were put in a three charts, one for each prototype, where each line represents a question (Q1 - Q10) and each row a participant. The cells were colored according to the achieved points in red, orange, yellow and green, inspired by traffic lights. This serves for a better visual overview of the results in the chart. For easier readability, an average accuracy was calculated in percentage for each question and for each participant at the end of each line/row. Further, the difference of these averages from before and after was calculated and denoted as increase.

A similar chart was created for the confidence scale ratings. For each question participants were asked how confident they feel about their answer on a scale of *„1 - I guessed“* to *„5 - very sure“*. These were, again, oriented in a chart for each question and participant with a color scheme ranging from red to yellow to green. The averages were calculated and compared, this time with the total numbers rather than accuracy percentages.

Figure 7.2, Figure 7.3 and Figure 7.4 show the above described results. The top two charts represent the points on the multiple choice questions, left is from the pre-test, right from the post-test. The bottom two charts represent the confidence level ratings, again, left from the pre-test and right from the post-test. Figure 7.2 displays the results of the ten participants who tested the video prototype, Figure 7.3 that of the game prototype and Figure 7.4 that of the website prototype.

A paired t-test was performed for each prototype to check whether the difference between the average question accuracies from before and after testing them are statistically significant. The learning effects could be established as statistically significant for all prototypes. The values are as follows:

- For the video prototype the results from the pre-test (mean (M) = 79%, standard deviation (SD) = 0,15) and post-test (M = 91%, SD = 0,11) knowledge questions indicate a significant learning effect, t(9) = 3,03, p = .0143.

- For the mobile game prototype the results from the pre-test (M = 76%, SD = 0,17) and post-test (M = 89%, SD = 0,08) knowledge questions indicate a significant learning effect, t(9) = 3,21, p = .0107.
- For the website prototype the results from the pre-test (M = 80%, SD = 0,17) and post-test (M = 94%, SD = 0,07) knowledge questions indicate a significant learning effect, t(9) = 2,97, p = .0156.

An analogue paired t-test was performed for the average confidence of participants on each question before and after. Likewise a statistically significant effect could be determined for all prototypes. The values are as follows:

- For the video prototype the results from the pre-test (M = 2,84, SD = 0,37) and post-test (M = 4,28, SD = 0,3) confidence ratings indicate a significant increase in confidence, t(9) = 13,91, p = <.001.
- For the mobile game prototype the results from the pre-test (M = 2,99, SD = 0,5) and post-test (M = 4,3, SD = 0,38) confidence ratings indicate a significant increase in confidence, t(9) = 11,49, p = <.001.
- For the website prototype the results from the pre-test (M = 3,1, SD = 0,74) and post-test (M = 4,54, SD = 0,25) confidence ratings indicate a significant increase in confidence, t(9) = 7,38, p = <.001.

For all learning methods an improvement is noticeable at first sight, both from the color distribution as well as from the numeric values such as the average increase of the accuracy and the confidence level. Table 7.1 gives an overview of these mentioned numeric values which can also be found in the charts. According to these numbers, the website prototype has the highest increase in average accuracy of 14%, which is 1% in front of the other two prototypes. The increase of the average confidence is $1,44$ for the website and the video prototype and $1,33$ for the mobile game prototype.

Table 7.2 shows the accuracy and confidence values from the post-test grouped into ranges for each prototype. According to these values, the mobile game prototype and the website prototype have almost identical values. While the video prototype does not have

	Increase of Average Accuracy	**Increase of Average Confidence**
Video Prototype	13%	1,44
Mobile Game Prototype	13%	1,33
Website Prototype	14%	1,44

Table 7.1: Overview of the increases of average accuracy and average confidence from the pre-test to the post-test for each of the learning method prototypes.

	Accuracy Increase			Confidence Increase			
	<89%	90-99%	100%	<5%	6-15%	16-29%	>29%
Video Prototype	2	6	2	2	5	2	1
Mobile Game Prototype	3	3	4	3	4	1	2
Website Prototype	3	3	4	2	5	1	2

Table 7.2: Overview of the increases of accuracy and confidence grouped into ranges from the post-test for each of the learning method prototypes.

	Average Accuracy Post-Test	Average Confidence Post-Test
Video Prototype	91%	4,28
Mobile Game Prototype	89%	4,3
Website Prototype	94%	4,54

Table 7.3: Overview of the total average accuracy and average confidence from the post-tests for each of the learning method prototypes.

the highest average accuracy in total (91%, see Figure 7.2 or Table 7.3), it does have more participants with equal or above 90% accuracy which are eight compared to the other two methods who each have seven such participants. However such small differences may be attributed to a number of factors such as the small number of participants, variations in pre-knowledge or learning style differences / preferences and anomalies to name a few.

Table 7.3 displays the total average accuracy and average confidence values from the post-tests for each of the prototypes. These values suggest that the website prototype stands out as the best prototype, leading in both average accuracy and average confidence. The video prototype and mobile game prototype are close in both values, particularly the confidence is almost identical considering the small number of participants. However these numbers alone don't suggest the highest learning effect as they don't count for how much participants had previously already known or how confident they had felt or generally tend to feel.

Remarkable Participants

Participant	Pre Accuracy	Post Accuracy	Learning	Prototype	Preferences	Prototype Ranking
#12	53%	80%	27%	Animated Video	Books, Social Media/Blogs, Explanation Videos	Website, Video, Game
#26	53%	93%	40%	Animated Video	Presentations, Books, Explanation Videos	Video, Game, Website
#5	67%	100%	33%	Mobile Game	Presentations, Books, Websites, Explanation Videos	Game, Video, Website
#13	67%	67%	0%	Mobile Game	Explanation Videos	Game, Video, Website
#19	63%	100%	37%	Mobile Game	Books, Websites	Video, Game, Website
#25	53%	60%	7%	Mobile Game	Websites, Explanation Videos	Video, Website, Game
#4	80%	83%	3%	Website	Websites, Explanation Videos	Video, Website, Game

Figure 7.1: Table of participants with remarkable high or low learning outcome and their learning preferences as well as prototype ranking.

Figure 7.1 shows a table of participants who stood out from other participants with a remarkable high or low learning outcome. Note that many participants already had a rather high accuracy in the pre-test which is why naturally these participants can't have much of a visible learning outcome in the identical post-test. For those participants whose learning outcome was low, it was interesting to look at whether the assigned prototype did not match their learning preferences. Hence the table additionally shows which prototype participants used and the learning preferences they indicated in a multiple choice question of the pre-test. Additionally, the ranking of the prototypes participants stated in the interview at the end of the sessions is shown in the right column.

Both remarkable participants who used the animated video prototype, which is Participant #12 with a low learning outcome and Participant #26 with a high learning outcome, also indicated explanation videos as one of their preferences. None of the participants in Table 7.1 who used the mobile game prototype also indicated learning games as a preference of theirs. Neither those with a high learning outcome nor those with a low learning outcome. However it should be noted, that out of 30 participants only two indicated learning games as one of their learning preferences. Participant #4 with a low learning outcome who used the website prototype indicated websites in their learning preferences. This comparison gives no insights into whether the learning outcome with a particular learning method prototype is dependent on participants learning preference.

The ranking of the prototypes also doesn't allow for conclusions as in two out of seven cases they are not in compliance with the learning outcome, which is for Participant #19 and #13. For the remaining five participants, it either applies they showed a high learning outcome with the tested prototype being their top ranking or they showed a low learning outcome with the tested prototype not being their top ranking.

All in all, while there are some small differences in numeric values, the prototypes seem to have performed rather similar. The numeric values of the website prototype tend to lead slightly ahead of the other two prototypes, however followed closely by the other two prototypes. None of the prototypes performed significantly poor or significantly better.

Video Prototype - Learning Effect

Participant	Pre-Test Knowledge #2	#6	#8	#12	#14	#18	#20	#24	#26	#30	Accuracy	Post-Test Knowledge #2	#6	#8	#12	#14	#18	#20	#24	#26	#30	Accuracy	Increase
	Achieved Points per Quesion											Achieved Points per Quesion											
Q1	3	3	3	1	3	3	1	3	0	1	70%	3	3	3	3	3	3	3	3	2	3	97%	27%
Q2	3	2	3	1	2	1	2	2	2	2	67%	3	3	3	3	3	3	3	3	3	2	97%	30%
Q3	3	3	3	2	3	3	3	3	3	3	97%	3	3	3	3	3	3	3	3	3	3	100%	3%
Q4	3	1	2	1	2	1	2	1	2	2	57%	3	1	2	1	3	2	2	2	3	2	73%	17%
Q5	3	2	3	2	3	2	3	1	2	3	80%	3	1	2	2	3	2	2	1	2	2	70%	-10%
Q6	3	3	3	3	3	3	3	3	2	3	97%	3	2	3	1	3	3	3	3	3	3	93%	-3%
Q7	3	3	3	1	3	3	3	3	1	3	87%	3	2	3	3	3	3	3	3	3	3	100%	13%
Q8	3	3	3	3	3	3	3	2	1	2	87%	3	2	3	3	3	3	3	3	3	2	97%	10%
Q9	2	2	3	1	2	2	2	2	0	2	60%	3	1	2	2	3	3	2	3	3	3	87%	27%
Q10	3	3	3	1	3	3	3	1	3	3	87%	3	2	3	3	3	3	3	3	3	3	100%	13%
Accuracy	97%	83%	97%	53%	90%	80%	83%	70%	53%	80%	*Avg.* 79%	100%	90%	90%	80%	100%	93%	90%	90%	93%	87%	*Avg.* 91%	
Increase												3%	7%	-7%	27%	10%	13%	7%	20%	40%	7%		*Avg.* 13%
	Confidence Level										Average	Confidence Level										Average	Increase
Q1	5	5	4	1	2	2	3	4	2	3	3,1	5	5	5	2	4	5	4	5	3	4	4,2	1,1
Q2	5	4	2	1	2	3	3	4	2	2	2,8	5	5	5	4	5	5	4	5	4	4	4,6	1,8
Q3	5	3	4	1	1	4	4	2	4	3	3,1	5	5	4	2	5	5	4	4	4	4	4,2	1,1
Q4	5	2	1	2	1	4	3	3	1	2	2,4	5	5	5	3	3	4	4	4	5	4	4,2	1,8
Q5	5	2	2	2	1	4	1	2	1	2	2,2	5	5	5	3	3	5	4	5	2	4	4,1	1,9
Q6	3	4	5	1	1	2	4	3	2	2	2,7	5	4	5	2	3	4	4	5	2	4	3,8	1,1
Q7	5	5	5	1	5	1	5	3	1	4	3,5	5	5	5	4	5	5	5	5	5	4	4,8	1,3
Q8	5	3	3	1	4	3	3	2	3	3	3	5	5	4	3	5	5	4	5	4	4	4,4	1,4
Q9	3	3	5	2	4	1	2	4	1	3	2,8	5	5	5	3	3	4	4	5	2	4	4	1,2
Q10	5	2	5	1	1	2	2	2	4	4	2,8	5	5	5	4	5	5	5	2	5	4	4,5	1,7
Average	4,6	3,3	3,6	1,3	2,2	2,6	3	2,9	2,1	2,8	*Avg.* 2,84	5	4,9	4,8	3	4,1	4,7	4,2	4,5	3,6	4	*Avg.* 4,28	
Increase												0,40	1,60	1,20	1,70	1,90	2,10	1,20	1,60	1,50	1,20		*Avg.* 1,44

Figure 7.2: Results for the video prototype: Multiple choice question points (0-3) for each question/participant for the pre- and post-test in the top two charts. Confidence level ratings (1-5) for each question/participant for the pre- and post-test in the bottom two charts.

Mobile Game Prototype - Learning Effect

Pre-Test Knowledge – Achieved Points per Quesion

Participant	#5	#7	#11	#13	#17	#19	#23	#25	#29	#31	Accuracy
Q1	1	3	3	1	3	3	3	1	3	3	80%
Q2	3	3	2	1	2	2	2	1	1	3	67%
Q3	3	3	3	3	3	3	3	1	3	3	93%
Q4	1	3	2	0	3	0	2	2	1	3	57%
Q5	1	3	3	1	1	1	1	1	1	2	50%
Q6	3	3	3	3	3	3	3	3	3	3	100%
Q7	3	3	3	3	3	3	3	3	3	3	100%
Q8	1	3	1	3	3	1	1	1	3	3	67%
Q9	3	2	3	2	2	2	2	2	2	2	73%
Q10	1	3	3	3	3	1	3	1	3	1	73%
Accuracy	67%	97%	87%	67%	87%	63%	77%	53%	77%	87%	*Avg.* 76%

Post-Test Knowledge – Achieved Points per Quesion

Participant	#5	#7	#11	#13	#17	#19	#23	#25	#29	#31	Accuracy	Increase
Q1	3	3	3	3	3	3	3	0	3	3	90%	10%
Q2	3	3	3	1	3	3	3	2	1	3	83%	17%
Q3	3	3	3	3	3	3	3	1	3	3	93%	0%
Q4	3	3	3	2	3	3	3	2	2	3	90%	33%
Q5	3	3	3	1	1	3	3	1	2	2	73%	23%
Q6	3	3	3	1	3	3	3	3	3	3	93%	-7%
Q7	3	3	3	3	3	3	3	3	3	3	100%	0%
Q8	3	3	3	1	3	3	2	1	3	3	83%	17%
Q9	3	3	3	2	2	3	3	2	2	2	83%	10%
Q10	3	3	3	3	3	3	3	3	3	3	100%	27%
Accuracy	100%	100%	100%	67%	90%	100%	97%	60%	83%	93%	*Avg.* 89%	
Increase	33%	3%	13%	0%	3%	37%	20%	7%	7%	7%		*Avg.* 13%

Pre-Test Knowledge – Confidence Level

Participant	#5	#7	#11	#13	#17	#19	#23	#25	#29	#31	Average
Q1	1	5	4	3	5	1	4	5	3	3	3,4
Q2	2	5	3	1	4	1	3	3	3	4	2,9
Q3	1	4	4	3	4	1	2	2	3	4	2,8
Q4	1	4	4	3	5	1	1	3	5	4	3,1
Q5	1	4	3	1	3	1	1	2	5	3	2,4
Q6	3	4	4	4	3	1	2	4	5	5	3,5
Q7	3	5	2	5	5	1	5	3	5	5	3,9
Q8	1	4	1	3	3	1	2	1	3	4	2,3
Q9	3	5	4	1	5	1	1	2	2	5	2,9
Q10	2	5	2	2	5	1	1	3	5	1	2,7
Average	1,8	4,5	3,1	2,6	4,2	1	2,2	2,8	3,9	3,8	*Avg.* 2,99

Post-Test Knowledge – Confidence Level

Participant	#5	#7	#11	#13	#17	#19	#23	#25	#29	#31	Average	Increase
Q1	5	5	5	4	5	5	5	4	4	4	4,6	1,2
Q2	5	5	5	4	4	4	5	3	4	5	4,4	1,5
Q3	5	5	5	3	4	5	4	2	4	4	4,1	1,3
Q4	3	4	4	5	5	4	5	3	4	4	4,1	1
Q5	4	5	5	3	4	5	4	2	4	4	4	1,6
Q6	5	5	5	4	5	5	4	4	4	5	4,6	1,1
Q7	4	5	4	5	5	5	5	4	5	5	4,7	0,8
Q8	3	5	4	3	3	4	3	3	4	4	3,6	1,3
Q9	3	5	5	4	5	3	4	3	4	5	4,1	1,2
Q10	5	5	5	5	5	5	5	3	5	5	4,8	2,1
Average	4,2	4,9	4,7	4	4,5	4,5	4,4	3,1	4,2	4,5	*Avg.* 4,3	
Increase	2,40	0,40	1,60	1,40	0,30	3,50	2,20	0,30	0,30	0,70		*Avg.* 1,33

Figure 7.3: Results for the mobile game prototype: Multiple choice question points (0-3) for each question/participant for the pre- and post-test in the top two charts. Confidence level ratings (1-5) for each question/participant for the pre- and post-test in the bottom two charts.

Website Prototype - Learning Effect

Pre-Test Knowledge — Achieved Points per Quesion

Participant	#3	#4	#9	#10	#15	#16	#21	#22	#27	#28	Accuracy
Q1	3	3	3	3	3	3	1	3	3	3	93%
Q2	1	1	1	1	2	3	2	3	2	1	57%
Q3	3	1	3	3	3	3	3	3	3	3	93%
Q4	3	2	1	2	1	2	2	2	2	1	60%
Q5	1	3	1	3	1	3	2	3	2	2	70%
Q6	1	3	3	3	3	3	3	3	3	3	93%
Q7	3	3	3	3	3	3	3	3	3	3	100%
Q8	3	3	3	3	2	3	3	3	2	3	93%
Q9	2	2	2	2	2	2	2	2	0	2	60%
Q10	3	3	1	3	1	3	3	1	3	3	80%
Accuracy	77%	80%	70%	87%	70%	93%	80%	87%	77%	80%	Avg. 80%

Post-Test Knowledge — Achieved Points per Quesion

Participant	#3	#4	#9	#10	#15	#16	#21	#22	#27	#28	Accuracy	Increase
Q1	2	2	3	3	3	3	3	3	3	3	93%	0%
Q2	3	3	3	3	3	3	3	3	3	3	100%	43%
Q3	2	1	3	3	3	3	3	3	3	3	90%	-3%
Q4	2	2	3	3	3	2	1	3	2	3	80%	20%
Q5	2	3	3	3	3	3	2	3	1	3	87%	17%
Q6	3	3	3	3	3	3	3	3	3	3	100%	7%
Q7	3	3	3	3	3	3	3	3	3	3	100%	0%
Q8	3	3	3	3	3	3	3	3	3	3	100%	7%
Q9	3	2	3	3	3	3	3	2	2	3	90%	30%
Q10	3	3	3	3	3	3	3	3	3	3	100%	20%
Accuracy	87%	83%	100%	100%	100%	97%	90%	97%	87%	100%	Avg. 94%	
Increase	10%	3%	30%	13%	30%	3%	10%	10%	10%	20%		Avg. 14%

Pre-Test Knowledge — Confidence Level

Participant	#3	#4	#9	#10	#15	#16	#21	#22	#27	#28	Average
Q1	4	3	4	3	3	5	3	5	3	5	3,8
Q2	4	4	2	4	2	4	5	5	2	2	3,4
Q3	2	1	1	4	2	3	4	5	4	5	3,1
Q4	2	3	3	3	1	2	5	4	2	1	2,6
Q5	3	2	1	3	1	2	4	5	2	1	2,4
Q6	1	1	3	3	1	2	5	5	2	2	2,5
Q7	4	5	4	5	4	4	5	5	5	5	4,6
Q8	4	1	4	5	2	2	5	5	3	5	3,6
Q9	3	2	3	2	3	3	1	5	1	1	2,4
Q10	4	1	1	5	1	4	4	4	1	1	2,6
Average	3,1	2,3	2,6	3,7	2	3,1	4,1	4,8	2,5	2,8	Avg. 3,1

Post-Test Knowledge — Confidence Level

Participant	#3	#4	#9	#10	#15	#16	#21	#22	#27	#28	Average	Increase
Q1	5	4	5	5	5	4	4	5	4	5	4,6	0,8
Q2	5	5	5	5	4	4	5	5	5	5	4,8	1,4
Q3	4	2	4	5	5	3	5	5	5	5	4,3	1,2
Q4	4	5	3	5	4	4	4	5	4	5	4,3	1,7
Q5	4	5	1	5	5	4	5	5	4	5	4,3	1,9
Q6	3	5	5	5	4	2	4	5	5	5	4,3	1,8
Q7	5	5	5	5	5	4	5	5	5	5	4,9	0,3
Q8	4	5	4	5	5	4	5	5	4	5	4,6	1
Q9	4	4	5	5	4	3	4	5	5	5	4,4	2
Q10	5	5	5	5	5	4	5	5	5	5	4,9	2,3
Average	4,3	4,5	4,2	5	4,6	3,6	4,6	5	4,6	5	Avg. 4,54	
Increase	1,20	2,20	1,60	1,30	2,60	0,50	0,50	0,20	2,10	2,20		Avg. 1,44

Figure 7.4: Results for the website prototype: Multiple choice question points (0-3) for each question/participant for the pre- and post-test in the top two charts. Confidence level ratings (1-5) for each question/participant for the pre- and post-test in the bottom two charts.

Qualitative Results

These quantitative values however are not useful without a qualitative counter part. The theoretical best learning method is not useful if people do not use it for any reason. Among other questions in the interview at the end of the sessions, participants were asked to rank the learning methods, with the first rank being their favorite. The ranking on its own would be considered quantitative data. The video was on average ranked at place 1.43, the website at place 2.23 and the game at place 2.33. However, participants were also asked to argue why they chose this ranking, which method they prefer for which purpose, where potential uses for each of them are and how they prefer to learn and why. These answers were collected and filtered into statements regarding the learning methods themselves rather than specific feedback on the prototypes. They were then sorted into statements for each of the learning methods before categorizing them in thematic analysis inspired manner. The remarks were analyzed to find categories of similar arguments made by separate participants which relate to the research question. These results will be described below for each of the tested learning method prototypes: animated video, mobile game and website.

Video as a Learning Method Remarks

The video as a learning method received 63 different remarks. Six categories of repeating types of remarks were found.

- Combination of Visual and Auditory Stimuli

  It was noted in 16 statements, that being able to both seeing and hearing information is beneficial for their attention or learning effect. Participants noted that it helps them stay focused, understand better or remember better. The animated visuals were also positively noted in this context.

- Fast Overview or Entry Way into New Subjects

  Participants remarked that videos would provide a fast way to understand something, 15 remarks belong to this category. Five participants emphasized in their statement that it serves well to quickly understand the basics or rough foundations of some topic or quickly give an overview of something however without providing this overview or understanding into detail. Videos can serve to easily and quickly understand concepts according to this category of statements.

- Increased Comprehension

  Eleven remarks were made about being able to easier or better understand information with videos. These remarks stated that videos help understand something complicated, are good for intensive engagement, or that they learn or remember best from videos. However in this category participants did not state a reason for why videos increase their comprehension.

- Passive Engagement or Not Exhausting

  This category was formed of four comments that deal with videos being not exhausting to learn from. Two of them stated that they can passively consume content without much effort. *„Sich berieseln lassen“* as one participant expressed this state in German language. The other two argued that they don't have to read, which is an advantage to them.

- Rewind Functionality

  The rewind functionality of videos was positively mentioned by five participants. This enables them to watch parts again if they feel they missed something.

- Tediousness and Impatience

  Finally, six remarks were made about videos being tedious to consume in a learning context. The reasons for this vary. Two become impatient waiting for the content they are looking for from the beginning. Three think it is easier to reread something than rewind and rewatch, partly because it can be hard to find the part they are looking for again or because the inhibition level is higher than to reread something.

Mobile Game as a Learning Method Remarks

The mobile game as a learning method received 58 remarks. Six categories were found which will be described in the following list.

- Motivating, Fun and Playfulness

  The game as a learning method was described to be motivating and fun in seven statements. Participants noted that playfully approaching content is refreshing, interesting, something different and fun which also helps them learn and/or remember.

- Experiencing and interactively experimenting with learning material

  A theme of participants being able to interactively find out how something works by trying and experimenting themselves with it stood out in eleven statements. Participants noticed that the interactivity of doing something themselves helps them understand processes, different states or generally how something works. One person stated that it helps [translated] *„because one has to think how it works and when it's wrong one has to find a solution and then understands in detail“* how and why it works that way.

- Repetition and Practicing

  Six participants noted that games can be a good way to learn from repetition and practicing for long-term memory. By repetitively interacting with the same information they argue this information could possibly be remembered for longer. This process was also compared to learning from index cards.

- As Entry Way or Activation

  Games were stated to serve well as an entry way into a new topic or as activation by four participants in this study. They noted that a good use for games could be as first experience for beginners.

- Suitable for Children

  Six participants remarked the major target group for games would be children or teenagers. Games could be used in schools or for younger children at home.

- Difficulty to Adjust for Contents and Low Level of Detail

  Seven participants felt that games are shallow in the sense that they don't teach into much detail. Comments were that it is difficult to adjust a game to appropriately reflect learning contents and that explanations distract from playing. One participant said that a game distracts from its learning content and would move learners away from the factual level for learning.

Website as a Learning Method Remarks

The website received 47 statements, which is significantly less than the video or mobile game. These were sorted into five categories as follows.

- Structure

  Good informative websites provide structure which helps to gain an overview of what is important according to four participants. In that way, through structure, websites can also serve as a *„documentation“* where they can look up specific information.

- Reread Sections, Repetition

  As a learning medium, websites are particularly useful for participants because it is easy and for some even automatic to read sentences or paragraphs again if they did not follow or understand. This was mentioned by six participants however one of them stated that rereading parts becomes tiring.

- Better and Detailed Understanding

  With eleven statements this is the most mentioned theme of arguments. According to these statements websites are the most informative of the three compared methods, are more extensive or detailed, allow for detailed understanding or deepening of knowledge.

- Precisely Looking Up Information

  Related to the first category *Structure*, six participants noted that an advantage of a websites is to be able to precisely look for the information they are looking for by directly searching the text or only skimming other contents that are not relevant to them. They can choose themselves which parts they want to skip, skim or read which makes it faster to find the information they need.

- Concentration and Active Reading

  Nine participants perceived that learning from websites require more concentration because they have to actively read in order to ingest the information. For some, this is a positive thing in the context of learning as they are more focused while for others this is exhausting and too much reading.

Taking these themes into consideration it seems that participants see a place for all three learning methods. However their favorite in the quantitative ranking, far ahead is the video which was on average ranked at place 1.43, the website at place 2.23 and the game at place 2.33. Participants were then asked to reason their ranking choice. Mentioned advantages of the video are that it is a visual and auditory medium, gives a fast overview and facilitates understanding. These advantages make it an efficient and effortless learning method for familiarization with a new topic such as blockchain. The website was perceived as a learning method to study and learn something into more detail in a focused manner. However the research question deals with familiarization rather than detailed informing which speaks for the video as the more realistic option for most non-experts. This depends on the type and extent of interest as well as amount of motivation users have. Finally, the game was seen as a learning method that needs more time, is sometimes tedious but yet convinces with other advantages such as being able to experiment, or practice. This could make it a suitable method for people who already have an interest in technical processes and want to interact with the process, find out the mechanics and enjoy learning by playing, irrespective of their prior knowledge. However it seems unsuitable for someone who just quickly wants to acquaint themselves with some basics. This leads to the finding that all three learning methods are suitable and viable choices for familiarization with blockchain, however preferences depend on the users' intention.

7.2 Impression and Subjective Level of Comfort

The second research question is:

> **RQ2:** Does this increased knowledge affect their subjective level of comfort?

To gain insights regarding the subjective level of comfort towards the blockchain technology, both quantitative and qualitative data was considered. Quantitative data was collected as part of the pre- and post-test and qualitative data in the semi-structured interview at the end of the sessions. Note that this work investigates learning methods and the learning effects of learning about the theoretical concept of blockchain technology itself, however without a focus on a specific application where blockchains are used.

Quantitative Results

To collect quantitative data regarding the subjective level of comfort towards the blockchain technology, a shortened and to this purpose adjusted version of the User Experience Questionnaire [LHS08] was utilized. It was given to the participants in the pre-test and the post-test after using all three prototypes. These answers were then digitalized to be able to compare and see changes.

Figure 7.5 shows a visualization of the data. The adjective couples were ordered into what would be considered positive on the right side and undesirable on the left side. The colored fields in the middle section signify the Likert scale with numbers indicating how many participants chose the respective value on the scale. Each adjective couple has two lines, the top line shows the results of the pre-test, the bottom line that of the post-test. The colors were added to help identify the frequent answers easier. Furthermore, an average value was calculated which can be found in the column denoted as *„avg“*. The average was calculated by giving the Likert scale positions numbers from -3 to 3, assuming the middle choice is 0 and the choice furthest on the positive side 3. This value however is to be treated with caution as it is subjective what is considered positive / undesirable and therefore which side is to be given the positive / negative numeric values. Taking these average values, a difference was calculated to show the changes from pre-test to post-test.

A paired t-test was performed to check whether the average subjective impresssion of participants changed in a statistically significant way from before and after learning about the blockchain technology. The results from the pre-test (M = 0,95, SD = 0,64) and the post-test (M = 1,38, SD = 0,57) showed a statistically significant improvement in participants subjective impression, t(29) = 6,95, p = <.001.

Looking at the difference values for individual adjective pairs, the highest changes are apparent in the *„understandable - not understandable“* pair with a positive change of 1.43 and the *„difficult to learn - easy to learn“* pair with a positive change of 1.17. This means, that on average participants rated these with more than one field towards the *„understandable“* / *„easy to learn“* side. Participants further found the blockchain technology to be more clear, easy, inventive, secure and exciting with each more than one half of a Likert field positive change. Particularly the secure characteristic is interesting and particularly important to consider for businesses who are unsure of whether to inform their clients of the technology. There are only few "negative" changes, most of them however minor, the highest negative change is -0.2 with participants finding blockchain more *„usual“* than *„leading edge“* after learning about it. This change however could also be considered positive as it could be interpreted as participants feeling more comfortable with the technology as it is less mysterious and complicated than before. The noticeably highest votes were given to the *„interesting - not interesting“* pair. This result however could be biased by the fact that participants voluntarily signed up for a blockchain user study and therefore might not be a valid representation of the population as they might have chosen to participate because of their interest in the blockchain technology.

Taking these quantitative numeric values it could be interpreted that yes, an increased knowledge does affect subjective level of comfort in a positive way. However, it's also possible that the prototypes were designed in a friendly way so that it would appear more positive. It is essentially impossible to design anything without making people who experience it feel something towards the artifact and its' thematic contents which is again subjective and depends on personal previous experiences and preference amongst others.

Because of these potential effects of the prototype designs it was interesting to look at differences in the UEQ results depending on which prototype the participants tested. Note that the UEQ in the post-test was given to the participants after testing all three prototypes which means one prototype in full and the remaining two in shortened versions. For this reason these results are to be considered with caution as by this time all three prototypes had left an impression on the participants.

Figure 7.6 shows the results of the UEQ in which the participants are grouped by the prototype they tested on the horizontal axis. The adjective pairs are shown on the vertical axis for the pre-test on the top and the post-test on the bottom. The ratings were analyzed on a scale from -3 to 3 with 0 being the neutral, middle option on the Likert scale of the UEQ. The adjective pairs were again ordered into what would be considered positive on the positive side of the scale (3) and the undesirable on the negative side of the scale (-3). The cells were colored from red to yellow to green following the traffic light analogy for easier visual overview. The representation also shows the average of each column and row of ratings as well as the differences between the averages of the pre-test and post-test denoted as *„dif"*.

The averages and differences were scanned for remarkable distinctions between the prototypes. It was considered remarkable when both the difference and the average rating of the pair in the post-test was significantly higher or lower than that of the other prototypes. For example in some cases, the difference was remarkable however the averages in the post-test were similar which means, that these participants had a different impression in the pre-test which however was not influenced by the tested prototype and rather a bias due to the small number of participants.

The remarkable distinctions were highlighted in bold and/or red in the post-test section of the representation. The numbers show a tendency of participants who tested the mobile game to find blockchain more *„conventional"* than participants who tested the animated video or website. This could mean that the mobile game explained the technology in a way that it appeared easy which would be positive. It could also mean that the puzzles and playful parts of this prototype were familiar which reflected on the technology in a way that it seemed conventional rather than inventive. Participants who tested the website showed an increase in the impression of the blockchain technology as being *„supportive"* and *„good"* while the other methods seemed to convey the opposite. This is interesting as particularly the website and the animated video are very similar in the wording and images they use. Finally, the participants who tested the animated video found the technology to be *„easier to learn"* than participants who tested the other prototypes. This could mean that the video was easy to follow and made it appear less complicated or have other reasons.

	not useful less uncomfortable		same		useful more comfortable
Did you find the information on blockchain useful?	0	0	1	10	19
Are you now more or less interested in blockchain?	0	1	10	11	8
How comfortable would you feel to use an application that stores and communicates data through a blockchain?	1	2	5	12	10

Table 7.4: Results of additional questions asked about participants' impression on Likert scales. Numbers represent the amount of participants per Likert scale choice. The Likert scales were oriented according to the top line.

As part of the post-test, participants were also directly asked whether they found the information on blockchain presented in the prototypes useful, whether they are now more or less interested in blockchain and whether they would feel comfortable using an application that runs with blockchain. The results are represented in Table 7.4.
Almost all participants found the information useful, only one participant chose the neutral middle option. Only one person is less interested, the rest almost equally spreads across from being the same interested to being more interested than before the user study. The majority would feel comfortable using an application that operates with blockchain data storage, three participants are uncomfortable. However, the last question does not imply the effects of the study within the question, meaning that participants might have felt uncomfortable/comfortable before the study and it just didn't change that perception.

In particular the result that participants found the information useful is relevant as it suggests a potential to the market. In combination with the result that participants were more interested in blockchain after learning about it, implies that suspicion or negative connotations of blockchain could potentially be alleviated by informing people. Finally, this could also have an effect on the level of comfort, which is also suggested from the results of the UEQ adjective pairs.

Impression Shift before/after learning prototypes

Adjective/Likert Scale									avg	dif		
boring	pre	0	1	4	2	7	4	12	1,50		pre	exciting
	post	0	0	1	2	6	6	15	2,07	0,57	post	
not understandable	pre	1	4	6	7	8	2	2	0,03		pre	understandable
	post	0	0	1	1	15	9	4	1,47	1,43	post	
conventional	pre	2	2	3	8	2	8	5	0,67		pre	inventive
	post	1	1	2	2	6	9	9	1,47	0,80	post	
not interesting	pre	0	0	1	2	7	6	14	2,00		pre	interesting
	post	0	1	0	2	4	10	13	2,03	0,03	post	
obstructive	pre	0	1	0	6	4	12	7	1,57		pre	supportive
	post	0	0	1	2	12	10	5	1,53	-0,03	post	
bad	pre	0	0	0	7	6	11	6	1,53		pre	good
	post	0	1	0	4	6	11	8	1,67	0,13	post	
unlikable	pre	0	0	1	9	12	3	5	1,07		pre	pleasing
	post	0	0	1	10	9	7	3	1,03	-0,03	post	
usual	pre	0	0	1	0	6	15	7	1,93		pre	leading edge
	post	0	0	2	1	8	11	8	1,73	-0,20	post	
not secure	pre	0	1	3	2	8	12	4	1,30		pre	secure
	post	0	0	1	3	4	10	12	1,97	0,67	post	
complicated	pre	3	8	11	4	3	1	0	-1,03		pre	easy
	post	2	3	10	6	4	4	1	-0,23	0,80	post	
dull	pre	0	0	1	8	9	10	2	1,13		pre	activating
	post	0	0	0	7	12	9	2	1,20	0,07	post	
confusing	pre	1	7	8	2	8	3	1	-0,27		pre	clear
	post	0	1	4	7	11	6	1	0,67	0,93	post	
unpleasant	pre	0	0	7	10	7	4	2	0,47		pre	pleasant
	post	0	0	2	10	6	11	1	0,97	0,50	post	
unattractive	pre	0	0	1	7	11	7	4	1,20		pre	attractive
	post	0	0	0	6	8	12	4	1,47	0,27	post	
unfriendly	pre	0	0	1	10	8	7	4	1,10		pre	friendly
	post	0	0	0	7	7	11	5	1,47	0,37	post	
difficult to learn	pre	0	5	10	6	8	1	0	-0,33		pre	easy to learn
	post	0	2	1	8	10	7	2	0,83	1,17	post	
conservative	pre	0	0	0	0	5	13	12	2,23		pre	innovative
	post	0	0	0	0	9	8	13	2,13	-0,10	post	

Figure 7.5: Results of the shortened User Experience Questionnaire bipolar items visualized as a table showing absolute numbers as well as average ratings.

Impression Shift grouped by Tested Prototype

Mobile Game

	Participant / Adjective Pair	#5	#7	#11	#13	#17	#19	#23	#25	#29	#31	avg	dif
Pre-Test	boring - exciting	0	3	1	3	3	-1	1	2	3	1	1,60	
	not understandable - understandable	-1	1	-2	-2	2	-1	-1	3	1	1	0,10	
	conventional - inventive	3	-1	-2	3	-3	2	3	-1	0	1	0,50	
	not interesting - interesting	1	3	1	3	3	0	3	2	3	2	2,10	
	obstructive - supportive	2	3	1	0	3	1	3	2	0	2	1,70	
	bad - good	0	3	1	3	3	0	2	2	3	2	1,90	
	unlikable - pleasing	0	3	0	0	3	1	1	0	0	0	0,80	
	usual - leading edge	2	1	2	2	-1	1	3		2	2	1,56	
	not secure - secure	1	3	2	-2	3	-1	2	1	2	1	1,20	
	complicated - easy	0	-1	-2	1	0	-1	-3	1	1	0	-0,40	
	dull - activating	0	1	1	2	3	1	2	0	1	0	1,10	
	confusing - clear	2	2	-2	1	3	-1	-3	1	1	2	0,60	
	unpleasant - pleasant	-1	2	0	2	3	0	-1	1	1	0	0,70	
	unattractive - attractive	1	3	0	3	3	1	1	0	2	1	1,50	
	unfriendly - friendly	-1	3	0	2	3	0	0	0	2	0	0,90	
	difficult to learn - easy to learn	1	0	-1	1	0	1	-2	0	1	1	0,20	
	conservative - innovative	2	3	2	2	3	1	3	2	3	2	2,30	
	avg	0,71	1,88	0,12	1,41	2,00	0,24	0,82	1,00	1,53	1,06	1,08	
Post-Test	boring - exciting	1	3	2	3	3	0	3	3	3	1	2,20	0,60
	not understandable - understandable	2	2	0	2	3	1	1	1	3	1	1,60	1,50
	conventional - inventive	2	3	3	2	3	1	3	-1	3	1	**2,00**	**1,50**
	not interesting - interesting	1	3	2	3	3	1	2	3	3	2	2,30	0,20
	obstructive - supportive	1	3	0	-1	2	1	2	2	1	1	**1,20**	**-0,50**
	bad - good	0	2	1	3	3	0	-2	2	3	1	**1,30**	**-0,60**
	unlikable - pleasing	0	2	0	1	2	0	1	0	-1	0	0,50	-0,30
	usual - leading edge	2	2	2	2	-1	1	3	0	-1	1	1,10	-0,46
	not secure - secure	0	3	3	3	3	-1	2	1	3	2	1,90	0,70
	complicated - easy	2	0	-1	2	3	1	-3	1	0	0	0,50	0,90
	dull - activating	1	1	0	2	3	0	2	0	2	0	1,10	0,00
	confusing - clear	1	1	-1	1	3	-1	-1	2	1	1	0,70	0,10
	unpleasant - pleasant	1	2	0	2	3	0	-1	2	-1	0	0,80	0,10
	unattractive - attractive	0	2	1	3	3	0	1	1	2	0	1,30	-0,20
	unfriendly - friendly	0	2	0	3	3	1	0	1	3	0	1,30	0,40
	difficult to learn - easy to learn	0	2	0	2	0	0	-2	2	3	1	**0,80**	**0,60**
	conservative - innovative	1	2	3	1	3	1	3	2	2	1	1,90	-0,40
	avg	0,88	2,06	0,88	2,00	2,47	0,35	0,82	1,29	1,71	0,76	1,32	
	dif	0,18	0,18	0,76	0,59	0,47	0,12	0,00	0,29	0,18	-0,29	0,25	

Animated Video

	Participant / Adjective Pair	#2	#6	#8	#12	#14	#18	#20	#24	#26	#30	avg	dif
Pre-Test	boring - exciting	3	1	2	-1	3	1	1	-1	2	1	1,2	
	not understandable - understandable	3	-1	0	-1	1	-2	0	0	0	1	0,1	
	conventional - inventive	3	0	2	0	0	0	0	2	0	1	0,8	
	not interesting - interesting	2	2	3	1	3	1	1	-1	3	1	1,6	
	obstructive - supportive	3	0	2	0	2	2	2	2	2	1	1,6	
	bad - good	3	0	0	1	1	0	2	1	2	2	1,2	
	unlikable - pleasing	3	1	1	1	0	1	1	1	1	1	1,1	
	usual - leading edge	3	1	2	2	2	2	1	2	2	2	1,9	
	not secure - secure	2	0	2	-1	0	1	1	2	-1	1	0,7	
	complicated - easy	-1	-2	-2	-1	-1	-1	-1	-1	-1	-2	-1,3	
	dull - activating	2	1	0	0	1	1	1	0	2	0	0,8	
	confusing - clear	1	1	-2	-1	0	-1	-1	0	-1	-1	-0,5	
	unpleasant - pleasant	-1	-1	-1	-1	0	0	0	1	0	0	-0,3	
	unattractive - attractive	2	1	1	0	0	0	2	1	2	0	0,9	
	unfriendly - friendly	2	1	0	0	0	1	1	1	1	1	0,8	
	difficult to learn - easy to learn	1	1	-2	-1	-1	-1	0	-1	-1	-1	-0,6	
	conservative - innovative	1	1	2	1	1	2	3	2	3	2	1,8	
	avg	1,88	0,41	0,59	-0,06	0,71	0,41	0,82	0,65	0,94	0,59	0,69	
Post-Test	boring - exciting	3	2	2	1	3	2	1	1	3	1	1,9	0,7
	not understandable - understandable	3	2	1	1	1	2	1	1	1	1	1,4	1,3
	conventional - inventive	3	0	2	1	1	0	2	1	2	-2	**1**	**0,2**
	not interesting - interesting	3	2	2	1	3	2	-2	0	3	2	1,6	0
	obstructive - supportive	3	2	1	1	1	1	0	1	2	1	**1,3**	**-0,3**
	bad - good	3	1	0	1	0	1	1	2	3	2	**1,4**	**0,2**
	unlikable - pleasing	0	1	0	0	0	1	1	1	3	1	0,8	-0,3
	usual - leading edge	3	1	3	1	1	1	2	3	2	1	1,8	-0,1
	not secure - secure	3	2	2	0	1	2	3	2	1	2	1,8	1,1
	complicated - easy	1	-1	-1	-1	-1	2	-1	0	-1	0	-0,3	1
	dull - activating	2	1	1	1	0	1	1	1	2	1	1,1	0,3
	confusing - clear	1	1	-1	0	0	1	1	1	2	0	0,6	1,1
	unpleasant - pleasant	1	0	0	0	0	1	1	0	2	1	0,6	0,9
	unattractive - attractive	2	2	2	0	0	1	2	1	2	1	1,3	0,4
	unfriendly - friendly	2	2	1	0	0	2	1	1	2	1	1,2	0,4
	difficult to learn - easy to learn	1	1	0	0	2	3	2	0	1	1	**1,1**	**1,7**
	conservative - innovative	3	1	2	1	1	1	3	3	3	2	2	0,2
	avg	2,18	1,18	1,00	0,47	0,76	1,41	1,12	1,12	1,94	0,94		
	dif	0,29	0,76	0,41	0,53	0,06	1,00	0,29	0,47	1,00	0,35		

Website

	Participant / Adjective Pair	#3	#4	#9	#10	#15	#16	#21	#22	#27	#28	avg	dif
Pre-Test	boring - exciting	-2	-1	0	3	3	3	3	3	2	3	1,7	
	not understandable - understandable	-3	-2	-1	1	0	2	0	1	1	0	-0,1	
	conventional - inventive	-1	-2	2	2	2	2	-3	3	0	2	0,7	
	not interesting - interesting	0	1	2	3	3	3	3	2	3	3	2,3	
	obstructive - supportive	0	-2	0	1	3	2	3	2	2	3	1,4	
	bad - good	0	1	2	1	2	0	3	2	2	2	1,5	
	unlikable - pleasing	0	-1	1	2	2	0	2	3	3	1	1,3	
	usual - leading edge	2	3	2	1	3	1	3	3	2	3	2,3	
	not secure - secure	2	2	2	1	2	2	3	1	2	3	2	
	complicated - easy	-3	-2	-2	0	-1	2	-3	-2	-1	-2	-1,4	
	dull - activating	-1	0	1	2	3	2	2	2	2	2	1,5	
	confusing - clear	1	-2	-2	1	-2	1	-2	-1	-1	-2	-0,9	
	unpleasant - pleasant	0	1	0	1	1	2	-1	1	3	2	1	
	unattractive - attractive	1	1	1	2	3	1	0	2	2	-1	1,2	
	unfriendly - friendly	0	0	1	2	3	1	3	2	2	2	1,6	
	difficult to learn - easy to learn	-2	-1	-1	1	0	2	-2	-2	-1	0	-0,6	
	conservative - innovative	2	2	2	3	3	2	3	3	3	3	2,6	
	avg	-0,24	-0,12	0,59	1,59	1,76	1,65	1,00	1,47	1,53	1,41	1,06	
Post-Test	boring - exciting	-1	0	3	3	3	2	3	2	3	3	2,1	0,4
	not understandable - understandable	1	2	1	1	2	2	1	-1	3	2	1,4	1,5
	conventional - inventive	-1	2	2	2	3	2	-3	3	1	3	**1,4**	**0,7**
	not interesting - interesting	1	0	2	3	3	2	3	2	3	3	2,2	-0,1
	obstructive - supportive	2	2	1	1	3	2	3	2	3	2	**2,1**	**0,7**
	bad - good	2	2	2	2	3	2	3	2	3	2	**2,3**	**0,8**
	unlikable - pleasing	1	0	1	2	3	2	2	2	3	2	1,8	0,5
	usual - leading edge	1	2	2	3	2	2	3	3	2	3	2,3	0
	not secure - secure	2	3	3	3	3	2	0	1	2	3	2,2	0,2
	complicated - easy	-2	-1	-2	1	-2	2	0	-1	-1	-3	-0,9	0,5
	dull - activating	1	0	0	2	3	2	1	2	2	1	1,4	-0,1
	confusing - clear	0	2	1	2	2	2	0	-2	0	0	0,7	1,6
	unpleasant - pleasant	1	0	0	2	2	2	2	2	2	2	1,5	0,5
	unattractive - attractive	1	0	2	2	3	2	3	2	2	1	1,8	0,6
	unfriendly - friendly	0	1	2	2	3	2	3	2	2	2	1,9	0,3
	difficult to learn - easy to learn	1	1	1	2	-2	2	0	1	1	-1	**0,6**	**1,2**
	conservative - innovative	2	3	2	3	2	1	3	3	3	3	2,5	-0,1
	avg	0,71	1,12	1,35	2,12	2,12	1,94	1,59	1,47	2,00	1,65		
	dif	0,94	1,24	0,76	0,53	0,35	0,29	0,59	0,00	0,47	0,24		

Figure 7.6: Results of the shortened User Experience Questionnaire bipolar items visualized as matrices showing the ratings on a scale of -3 to 3 with participants grouped by tested prototype.

Qualitative Results

In addition to the quantitative data, qualitative data from the semi-structured interviews at the end of the sessions also provided some indications towards participants' subjective level of comfort towards blockchain technology. The handwritten notes that were taken during the interviews were digitalized per question theme. Two of these themes relate to this research question which are *Impressions* and *Usage* of blockchain. The two themes have statements from all thirty participants each. These statements were then taken and categorized, most of them were broken up into parts as well.

The *Impression* theme was divided into three categories, 22 remarks on participants' understanding and knowledge, 14 remarks on positive and four negative aspects. From the first sight at the categorized remarks, it is noticeable that there are more positive than negative remarks and most about participants understanding and knowledge before and after.

- Understanding and Knowledge

  Asking participants about their impressions of blockchain resulted in many answers about what they knew before and whether they learned something. 17 noted that they understand better and several that they are interested to learn more, four that they are not more or less interested than before.

- Positive Aspects

  Six of the positive statements note that there are interesting applications for blockchain in the future, five that blockchain technology is innovative, others remark other positive aspects such as not needing an intermediary, that it seems easier to use than before the study or that they think blockchain will improve things in the future.

- Negative Aspects

  There were only few, four, negative remarks which are that there are little applications where blockchain is better than a relational database, that the technology is too abstract, that intermediaries don't want that blockchain becomes common practice or that *„weird"* things could be saved in blocks that couldn't be deleted anymore such as child pornography.

In the interview, participants were asked whether they would use an application that uses blockchain and what factors would motivate or unsettle them. These answers make up the theme *Usage*. The remarks on *Usage* were divided into three categories as well. These were again positive aspects with 51 remarks, 26 remarks on doubts and insecurities and as a third category with 15 remarks conditions or requirements that participants would need in order to use an application with blockchain technology. It is noticeable that there are more "negative" remarks in the doubts and insecurities category than in the negative aspects category of the previous theme *„Impressions“*. This could be because participants were directly asked for unsettling issues.

- Positive Aspects

  In the positive remarks 23 participants mentioned the advantages that were illustrated in the prototypes such as blockchain being safe, forgery-proof, hard to manipulate, not depending on an intermediary, decentralized, transparent, not deletable, or anonymous. Three participants also want to promote innovation or research and would therefore want to use it.

- Doubts and Insecurities

  This category collected the doubts and insecurities that were noted. Five of these say that participants would like to know more and understand better in order to feel comfortable, four say that they are insecure simply because it is new and they don't have experiences with it. Other insecurities are about hackers that could manipulate the votes of the majority or system by calculating hashes faster (6), and about their data being stored without being able to delete it and legal aspects regarding the deletion of data (3).

- Conditions and Requirements

  15 participants stated conditions or requirements in one way or the other. Four participants noted that it would need to be little or no extra effort in order to for them to use it. Three said it depends which kind of their data is stored, four that it depends on the application. Three are indifferent as long as it makes something easier for them or when they don't notice that blockchain is being used for data in the application. One participant noted that she would need a friend or some reference of trust to used it, another noted that he would use it once it is more widespread in a few years maybe as he thinks it would be safer then.

Taking these insights from the qualitative interview it seems that participants had a predominantly positive impression of blockchain. Learning about the technology and understanding more about it seems to have encouraged them and made them feel more secure and comfortable about blockchain. However there are still some doubts and insecurities on their minds. It is unclear whether these might have emerged from learning and understanding more about blockchain. All in all participants seem to be more or at least equally interested than before the study and their impression seems to have improved or remained the same.

7.3 Abstraction Preference

The third research question is:

> **RQ3:** Which level of abstraction is appropriate so that non-expert users would know enough without feeling overwhelmed?

The level of abstraction in RQ3 is understood as in which ways ideas are simplified and abstracted from detailed and technical mathematical and computational concepts to understandable ideas in everyday language. In this work it is understood as in which level of detail and in which manner things are explained to non-experts. There is no scale on which the level of detail and manner of explanations can be measured. To get an idea of appropriate or preferred explanations, different ways the same concept was explained throughout the learning methods were compared as well as simply asking participants which explanations were helpful and which were confusing for them. For example a hash was explained as a fingerprint, a cryptographic code or a checksum (see 7.8a). While it could be argued which of these explanations is closest to the real implementation in blockchain systems, in this work the focus was to find preferences and try to dissect which ways of explaining helped participants understand concepts.

Quantitative Results

One way it was approached to quantitatively gain insights regarding levels of abstraction was to find different ways the same contents were explained or illustrated in the prototypes. Participants were then asked in the post-test which of the abstractions helped them to understand the respective concept best or which abstraction they preferred.

Figure 7.8 illustrates the abstractions as they were pictured in the post-test to remind the participants of the metaphors that were used in the prototypes to explain the concepts of hashes, blocks, cryptographic chaining, proof of work and deletion of data on blockchains. They were asked to choose for each of the concepts, which abstraction they liked the most. Multiple answers were allowed. They were also given the options *„None, easier analogies would be better.“* and *„None, more details would be better.“*.

Table 7.5 summarizes the results of the participants' preferences. Each line represents one of the concepts of which the abstractions are illustrated in Figure 7.8. The numbers are the amount of participants who chose that option.

The numbers show, that for hashes participants liked all three representations with a slight majority for the fingerprint analogy. Blocks were easiest to understand in the sketched imagery version that shows the different elements a block consists of. The most abstract representation, that it is a form of storage came out in second place. For cryptographic chains the depiction of overlapping blocks that are connected by fingerprints was preferred by two thirds of the participants while the other depictions had significantly less votes of seven and nine out of thirty. The votes for the concept of proof of work were distributed rather evenly across the three options with a preference for the analogy of the miner working with tools rather than the hourglass and the trial & error puzzle. Finally, deletion was best understood with the analogy of the eraser that erases the corresponding names out of the blocks without deleting the blocks themselves. 20 out of 30 participants voted for the eraser analogy, 9 for the anonymization and 7 for the mapping analogy.

Taking these results, it is still difficult to attempt a generalized answer to which level of abstraction is appropriate to convey blockchain principles to non-experts. From the results of the block abstraction preferences, one possible theory could be that people prefer either rather specific, tangible representations that are yet simplified and easy to understand such as the imagery of the block or they prefer rather abstract, unspecific representations that are not confusing or distracting by too many details. Something similar could be interpreted into the results from the Proof of Work (PoW) abstractions. For PoW people preferred the representation of a person with a tool which signifies that work needs to be done by someone while the hourglass is rather abstract and the puzzle may include details that are confusing and not necessarily relevant for the understanding of the basic concept. The representation with overlapping blocks might have been preferred due to the fact that it is easier visible that part of the previous block is included in the current block while this is less visible in the representation where hash-codes form this connection. Chains on the other hand might be too abstract without a way of envisioning how this works in practice.

For explaining blockchain concepts to non-experts this could mean that attention needs to be paid to where and how many details are included. While they may help to understand principles, that may also allow for confusion. Details should be used when they help envisioning concepts without adding too much of a mental load on the learners. Otherwise, keeping it abstract may be the better way of explaining.

Qualitative Results

Asking the participants in the interview about which explanation helped them understand or which explanation confused them also yielded qualitative data about abstractions. These comments were collected into two lists of comments, one for what would be considered positive and one for negative remarks. The positive list includes 67 remarks, the negative list consists of 47 remarks. They were then analyzed to find themes of similar remarks to be put into categories. This process yielded five categories for the positive list and five categories for the negative list.

In the positive list of 67 remarks two particular abstractions stood out for the participants which is the visualization of blocks with overlapping fingerprints as shown in Figure 7.7 and the hash formula that was used in the mobile game prototype. Further, participants found fingerprints and check sums to be good analogies for hashes. Decentralization was remarked to be understood well however without naming a particular abstraction that helped them. A general understanding formed the last category.

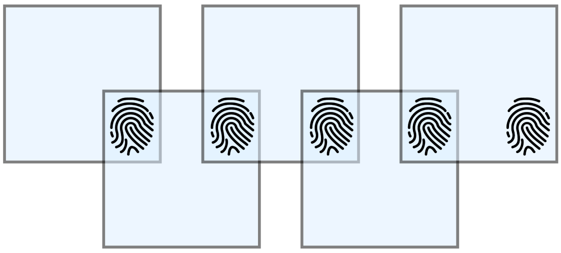


Figure 7.7: Visualization of blocks with overlapping fingerprints that was used in the video and website prototype.

- Visualization of blocks with overlapping fingerprints

  This particular visualization in Figure 7.7 was mentioned eight times by different participants. It was also the only visualization that was directly mentioned so often which suggests that it stuck in their mind. They described it as helpful, good for showing concatenation and efficient to teach. One person said it should be shown more often.

- Hash Formula in Game Prototype

  The hash formula which was used in the game prototype was remarked by four participants. The formula should help understand, or even force to understand, be helpful for people without prior knowledge, and serve well to show how blocks are concatenated in simplified terms.

- Hash Analogies of Fingerprints and Check Sums

  Hashes were understood well as nine participants stated. Analogies were helpful to understand hashes. Particularly the analogy of the fingerprint (3) and the check sum (2) was mentioned.

- Decentralization

  As an element that was understood well eight participants mentioned the decentralization however mostly without indication of how or why they found it easy to understand. One participant said the game prototype helped understand the consensus mechanism and another participant mentioned a visualization of interconnection between computers which was used in both the video and the website.

- General Understanding

  Eight participants stated that it was easy to obtain a general understanding. This was worded in different ways such as *„what blockchain is and how it roughly works“*, *„idea behind blockchain“*, *„basic concept“* *„introduction“* or *„blocks and structure“*. However in this category none of the comments included a reason for how of why this was easy to obtain.

Finally, there were 15 comments that didn't fit into the categories. These didn't include arguments on abstractions, they were rather comments on other elements they found easy to understand or imprecise feedback to the prototypes. However one participant mentioned that it was helpful that new words were explained straight away and two participants noted that visualizations help for understanding and/or remembering.

The list of the negative 47 remarks was significantly shorter than the positive list. These remarks however did not name specific abstractions that were confusing or in some other way poor for them. There were rather themes of remarks such as not enough information, confusing visualizations or confusing content such as Proof of Work or the consensus mechanism particularly in the mobile game prototype.

- Not Enough Information

  As a reoccurring theme the sense of *„not enough information"* became apparent in eight statements. It was remarked that there was too little information/detail, that it was too short or too much simplified. However, not all of these remarks said that this hindered them from understanding, partly participants would have simply been interested in knowing more or understanding better with more examples.

- Visualization or Representation Confusing

  Specific visualizations were remarked to have been confusing or in need of improvement in seven statements. These were representations that show blocks, what blocks contain, and how blocks are connected; graphics in the context of deletion of data, the eraser in the game prototype, and the representation of the check sum with a line above the total sum.

- Proof of Work and Miners

  A topic that was mentioned twelve times to have been confusing is Proof of Work and the related miners. While eight participants simply named this topic to have been difficult to understand, others were more specific. Statements were that it was difficult to understand what miners are needed for, that the game element was designed poorly, that the hourglass showing ten minutes was unclear or that miners could be difficult to understand for people who have no prior knowledge.

- Consensus Mechanism in Game Prototype

  Two participants named the consensus mechanism in the game prototype to have been confusing. One wondered what would happen if the actors would vote incorrect three times in a row. The other found the element of the hacker who steals money confusing and why or how the hacker would change 50% of the chain.

- Other Factors

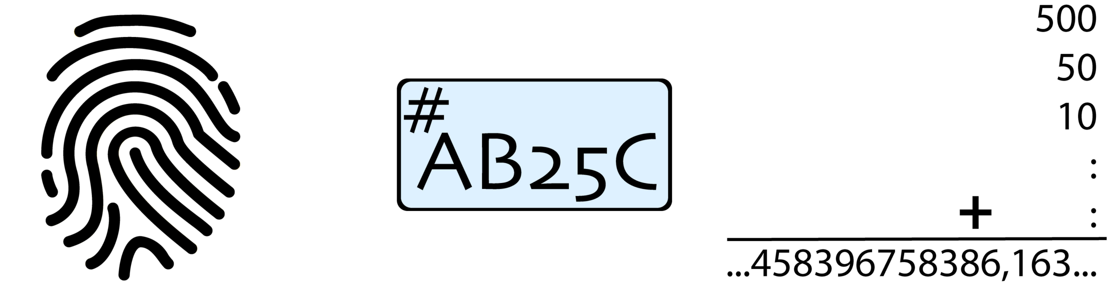
  Finally, other factors were grouped together into this last category of six statements. These include poor concentration, not taking a break, ambiguous multiple choice answers, unclear structure in the website of which image belongs to which paragraph and game elements being *„far-fetched“*.

The remaining twelve statements were mentions of elements that were difficult to understand however without an explanation of why these parts were particularly difficult for them.

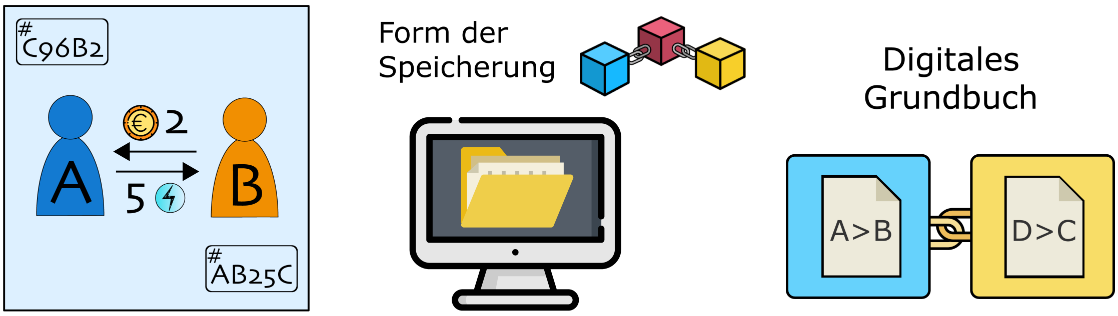
It should be noted, that many participants stated that they don't remember specific abstractions that were helpful or confusing for them which was not included in these lists of statements. This could be due to the fact that this was at the end of the study session and interview. Two specific abstractions were positively mentioned, the blocks with the overlapping fingerprint (see Figure 7.7) and the hash formula in the mobile game prototype. What they have in common is that they focus on one piece of information they attempt to show and leave the rest out. Also, they both allow the learner to to follow the making of something, which is a chain of blocks or a hash respectively. On the other hand the confusing topics of Proof of Work or the consensus mechanism both consist of a number of concepts that might have been too many at once. However, both these topics are already more comprehensive than a hash or a chain on their own. It could be considered to break them down into smaller parts or to simplify them more by leaving out details that are not necessarily relevant for beginners. The results give indication on a level of abstraction that was appropriate which were named in the first list. While the second list gives indications of instances where the level of abstraction was too high or low - not enough information or confusing, complicated information with however *„not enough information“* mostly being due to a higher interest in understanding better. These examples could be used to guide the level of abstraction for future prototypes or explanations for similar target groups.

	left	**middle**	**right**
Hashes (see Figure 7.8a)	Fingerprint 16	Cryptographic ID 14	Complex Checksum 13
Blocks (see Figure 7.8b)	Imagery 16	Form of Storage 13	Digital Ledger 8
Chaining (see Figure 7.8c	Overlapping Blocks 21	Chain Symbol 7	Connecting Hash-Codes 9
Proof of Work (see Figure 7.8d)	Miner with Tools 15	Hourglass 10	Trial & Error Puzzle 10
Deletion (see Figure 7.8e)	Deletion of Mapping 7	Anonymization 9	Erasing of Names 20

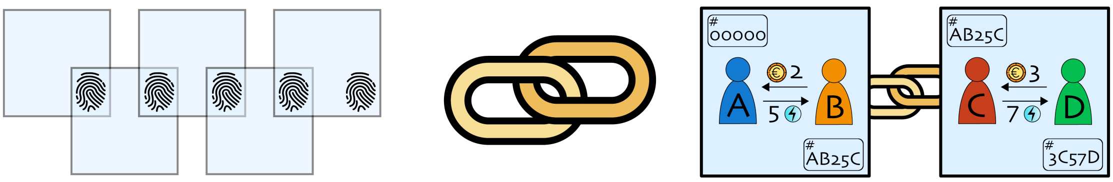
Table 7.5: Results of participants' preferences of abstractions, multiple answers were allowed. Left/middle/right refer to the respective options shown in Figure 7.8.



(a) Hash Abstractions



(b) Block Abstractions



(c) Cryptographic Chain Abstractions

(d) Proof of Work Abstractions

(e) Abstractions for Deletion of Data on Blockchains

Figure 7.8: Three different abstractions taken from the prototypes to explain each of the concepts: hashes, blocks, cryptographic chains, proof of work, and deletion of data

CHAPTER 8

Discussion

This work dealt with analyzing learning methods for blockchain technology on the motivation of providing information for non-experts so that they would feel more comfortable in using it and feel less insecure about the technology. This should enable them and more importantly leave them feeling enabled to use a number of applications or features and benefit from their opportunities. Especially with regard to the energy sector where more and more applications for households are developed.

While the technology is a back-end technology and should therefore be mostly invisible to people, people still seem to be interested, skeptical or curious about the technology as seen in the workshop, and from participants of the user study. This could be because it has been in the media mainly in the context of the cryptocurrency Bitcoin. However the technology can be used for many other applications on which the news and issues of Bitcoin don't apply. Hence a differentiation from Bitcoin to other blockchain applications makes sense in informational material.

Another thought on differentiation is that while there is information that could be provided to people who are interested and seek to learn in their free time, there could also be information that people *should* know from an ethical or even legal perspective. On the one hand it may seem peculiar that companies whose products or applications use blockchain technology would have to disclose details on the technical design of their back-end which could be considered intellectual property as Expert 2 from the expert interviews argued. On the other hand the technology has certain properties that has potential implications on data protection and privacy such as records being replicated and shared among participants or records being unerasable. An example for another technological component that has such a legal requirement of informing people are *„Cookies“*. However the current realization of this led to a suboptimal solution of people being annoyed by popup overlays that they have to close before being able to fully view a website. On the other side, providing information to people can also yield advantages as awareness for its properties of increased transparency and higher level of trust which would be on the other side of the differentiation, for interested people. A potential pitfall though is to overload them with information so that the result is an insecurity if they didn't understand the mentioned elements. In this sense less details, focusing on properties that can be conveyed in everyday language and that don't require an understanding for much of technological concepts could make sense for non-experts. Hence an interesting question is to determine what information people *should* know which could be very minimal and what information they could benefit from. The prototypes in this work probably still contained too much information or too many details that could be left out and still provide adequate satisfactory benefits for people but without leading to potential confusion or uncertainty.

The quantitative results of the learning methods revealed no clear *„winner"* in regards to participants' learning effect or increase of level of comfort. However the qualitative analysis showed some aspects that speak for or against each particular learning method. These can be seen in the results of the qualitative data from RQ1 in section 7.1. They lead to the idea that each method has their place depending on the context and target group that they are used. A tendency towards videos being the most *comfortable* method to learn from and gain an overview was apparent. While websites could provide more detailed information in a trustworthy source or a space to look for a particular piece of information that people may be interested in specifically. Games were perceived as interesting however for a younger audience or when they want to spend more time. However games are for most a fairly new learning method that they haven't tested and experienced which became apparent in the interviews and pre-test questionnaires. Hence another aspect that plays a role could be peoples' learning preferences and the thereby associated inhibition level of learning from other learning methods. In the user study the participants were randomly assigned a learning method and could not choose. However outside of this setting they might avoid to devote themselves to learning from a learning method that they don't feel comfortable with. Instead they might look for other material or completely change their minds about learning about blockchains when they would have been interested before.

The mobile game in particular received mixed reactions. Some participants perceived it as tedious and annoying while others enjoyed its motivating and fun properties. There was a tendency towards the mobile game to provide a smaller increase in the level of comfort than the other methods. This could be because some parts were confusing or frustrating to participants which could be due to the more active nature of games as players have to find solutions and understand or test what they have to do in order to complete the level while for the other methods learners are not forced to necessarily understand or do anything to move forward. Another issue is that it is a design challenge to fit the learning content into playful elements, particularly when the goal is not to rely on a quiz type of game. While a quiz based game may also provide advantages, games that integrate the information well into playful elements can be beneficial to learners when they can experience the effects of concepts that are hard to convey in words or images. An example for this is the puzzle type of game that was used for Proof of Work.

The puzzle was designed in a way that it would cost time to solve it and be somewhat random which was meant to reflect on the characteristics of Proof of Work in blockchains. However this may mean it is necessary for players to read additional text in order to recognize such parallels. The mobile game prototype of this work can be played without reading informational texts, however the learning effect is then compromised. Some participants found that the game is fun, motivational and gets them ambitious while others perceived it as time consuming and annoying to have to read so much text. These aspects and the higher production time and cost of a mobile game need to be carefully considered before opting for this learning method. It should be considered who the target group is. Games are likely more suitable for people who are either truly interested in learning in their free time, as this method may take longer or for some feel like it takes longer to provide the same amount of information as for example a video or website. It can also be suitable for museums or a school context, provided students are given enough time.

The purpose and context also play a role for choosing a learning method. It depends who is providing the information and how they seek to distribute it. For example a product in a box may include something like a flyer, a company may provide information or a link to a video on their website. Schools, museums or people at home may be more interested in an active experience and therefore opt for the game which however could also emotionally affect people through its playful elements. The themes that emerged from the qualitative results of RQ1 and RQ2 can give further insights into aspects to consider.

It should be mentioned, that the results could be subject to details within the design of the prototypes such as wording, graphical style, layout or similar. This was attempted to be kept similar between the prototypes in order to receive results that reflect on the learning methods rather than the design. A qualitative think aloud study that focuses on such details and their effects could provide insights into these aspects. Finally, this work perhaps also provided insights for other application areas that are not solely blockchain in the energy context, but may include teaching other technologies or complex learning topics.

CHAPTER 9

Recommendations

In this work learning methods in self-designed prototypes that aim to familiarize non-experts with blockchain technology were compared in a user study with 30 participants. Combined with a non-experts workshop, expert interviews and literature this yielded a number of insights for recommendations. These partly relate directly to blockchain technology and partly to digital learning methods themselves which could potentially be applied for various other scenarios of teaching about other technologies or complex learning topics through digital methods.

- Specifically the handling of data should be included in familiarizing non-experts with blockchains as the experts in the expert interviews argued it could be considered a legal requirement as well. This includes the replication and sharing of data among participants as well as the mostly unerasable data. The wording and presentation of this information should be considered carefully as to both adequately inform people so that they would understand what this means while on the other hand not confusing them by overloading them with information which could leave them feeling more insecure. Depending on the context, this should also be specifically tailored to how this handling of data is implemented in the application, for example when such information is given for a specific product.

- As the blockchain technology has been in the media there are several buzzwords that people have heard but may not understand which the non-experts workshop showed. Some of these center around Proof of Work, miners, and majority votes in the consensus mechanism context. In the prototypes these topics were addressed, however in the user study they were mentioned to have been confusing or to have created insecurities which had an effect on their level of comfort. As these topics are within common buzzwords and can be seen as advantages of the technology, these shouldn't be left out in explanations about blockchain. It should be carefully designed how detailed and in which wording and imagery these are explained so that they can be understood in enough depth without confusing people.

- The results of the user study, in particular that of RQ2 dealing with increased level of comfort, suggested that the amount of information that is given or number of different mentioned aspects are critical. Once an aspect is mentioned but not fully explained or not explained enough to peoples' understanding, it becomes a factor of confusion and insecurity as interpreted from the qualitative data. This relates to the seven principles for instructional animations by Mayer & Moreno [MM02], one of which is to exclude irrelevant or redundant distractions. For this reason, it should be carefully chosen which topics to include and carefully considered how to present them in a way that is as fundamental as possible without confusing through too many details. Such details could be offered as additional information at the end.
- Relating to the previous recommendation, somewhat of a simplicity has proven successful for the abstraction of contents. This became apparent from the results of RQ3 where particularly one visualization was remembered well by participants. This visualization is shown in Figure 7.7 and is rather simplistic, including little details, however showed one aspect well which is how blocks are chained using hashes. Similarly the hash formula from the mobile game prototype was mentioned to have helped understand hashes of blocks. This relates to what McGrath & Brown [MB05] noted about Drew Berry's medical science animations conveying only one concept at a time with a lot of scientific detail. In the context of blockchain it should be considered to use analogies and visuals that convey only one aspect while abstracting the rest away. Another option is to consecutively explain small parts and thereby build visualizations that include more and more details step by step.
- While the quantitative results for the learning effects of the prototypes didn't necessarily show a clear distinction, the qualitative results showed that they have different qualities in how it feels to learn from them to people. These ultimately may depend on peoples' learning preferences, however they can be more suitable for certain intended purposes and settings. Therefore such qualities should be considered when choosing a learning method for a certain setting or purpose. Examples for such qualities that were found in the user study of this work can be found for each of the learning method prototypes in the qualitative results for RQ1 presented in section 7.1.

To conclude, most of the recommendations are essentially about attempting to present information clearly to people without overloading them with information that may be unnecessarily complicated. The handling of data however is essential as it is a potential legal but also ethical question to adequately inform people about what happens with their data. Keeping information clear, structured and simple is in most cases successful leading to less confusion. Finally, the appropriate learning method should be chosen for the intended use according to its properties.

CHAPTER 10

Conclusion

This work looked at familiarizing non-experts with blockchain technologies. Literature and expert interviews showed, that there are reasons to inform about a backend technology besides alleviating insecurities and satisfying curiosity. The two main reasons are that it is being used more and more in applications for households such as in the peer-to-peer energy trading where people should be enabled to participate and take advantage of new possibilities while informing them of how the technology is handling their data. Particularly the handling of data, as they are replicated and shared amongst the participant network and can't be deleted as they are being chained to the data set becomes an ethical and legal requirement depending on the application and how it is implemented specifically.

As this is a somewhat delicate topic since it is a complicated technology for non-experts that has a controversial reputation in the media which already leads to a certain confusion and unclear buzzwords. Therefore the aim was to give clear and easily understandable information on the basics of blockchains that are relevant to non-experts. Hence the research questions were (RQ1) what learning methods have the highest learning effect in this context, (RQ2) does an increased knowledge effect peoples' subjective level of comfort regarding blockchain and (RQ3) which level of abstraction is appropriate for non-experts.

In a literature research the blockchain technology and its properties as well as a brief overview of learning methods and some learnings from digital learning methods were collected. The data from a workshop with non-experts that was held before the work for this thesis started was analyzed and complemented by interviews with experts to inform what information should be included in learning methods and how they should be presented. The workshop showed that participants were somewhat interested in the technology but not highly interested and could name several buzzwords however without understanding what they mean. Imagery and animation can support readers in following the content and grasp concepts easier. However especially then it is important to choose the wording in a way that it compliments the visuals and isn't confusing or ambiguous. In the expert interviews it was discussed whether and to what degree it makes sense to inform non-experts. In this regards especially the connection to the GDPR and the handling of data within the blockchain was highlighted. Otherwise people could benefit from understanding more about the technology by being able to benefit from its opportunities which would essentially include blockchains' characteristics of claiming to be safe, forgery-proof, immutable and operate without an intermediary. According to the experts the information should be kept simple with minimal technical details and instead emphasize use cases and interesting factors for the respective applications.

The results from these three elements, the literature, non-expert workshop and expert interviews informed the content and concept of the three learning prototypes that were designed for this work: an animated video with voice-over, a learning game for smartphones and a website. The information is, in large parts, conveyed using the same wording as well as imagery. By keeping these elements similar, it was attempted that the results of the user study would reflect the differences of the learning methods to a higher extent rather than the differences of wording, imagery and similar. In all of the learning tools the contents are divided into smaller portions of information with multiple-choice questions in between. They are meant to support the learning effect by reviewing information directly as well as keeping the learners active and attempting to create a less monotonous learning experience for them. These questions are also kept the same in each of the methods so that, again, the results could be compared meaningfully in the user study.

The video prototype is an animated illustration video that is 12 minutes and 32 seconds long and that was aimed to be light-hearted, sketch-like and friendly. The German voice-over was self-spoken, recorded and cut to go along with the animations. The mobile game is divided into five levels that successively build on each other. The mini games are puzzle-like and based on a time limit however the players can try as often as they like without negative consequences. Some animated elements were included for a playful feel such as flying coins, an electrocuted stick person or a hackers attack. For the website a majority of the explanations as well as graphics such as icons and illustrations were reused from the video or the game. In chapter 5 the prototypes are described including images to get a better idea of the appearance and feeling of the prototypes.

The prototypes were compared in a user study using pre- and post-tests and a semi-structured interview at the end thereby using both quantitative and qualitative methods to address the three research questions. The user study was conducted with 30 participants in individual sessions that took approximately 90-120 minutes. In order to adhere to the time frame, each participant tested one prototype in full and the remaining two in shortened versions. The post-test for the learning effect was conducted after the first prototype was tested, the rest of the post-test and the interview after all three prototypes were tested.

For the learning effect (RQ1), there were only small differences in quantitative values between the prototypes, where the website tends to lead slightly ahead of the other two prototypes. This could be attributed to the fact that people are most used to this form of learning or to the fact that participants were able to take as long as they needed with this prototype whereas with a video the inhibition level for rewinding might be higher in a user study setting. The qualitative results showed a number of properties for each of the prototypes that could be considered when choosing a learning method for a specific purpose or application. For the video, the visual and auditory combination was positively remarked and that it serves well to provide a quick overview with easy comprehension. It's passive consumption that is not exhaustive was also positively noted while finding specific things was perceived to be hard in a video. The website on the other hand was commended for its structure which makes it easy to find specific information and for being a comfortable learning method as participants are used to it. Negatively noted was that it is exhausting to read and requires active concentration for understanding. Finally, the game was perceived to be motivating, fun and good for repetition and practicing. Experiencing and experimenting with content was noted to be helpful for learning. However the game was also perceived as tedious by some and difficult to adjust to properly translate to learning contents.

The results showed that after learning about blockchains with the prototypes the subjective level of comfort and impression is higher (RQ2). A shortened version of the User Experience Questionnaire (UEQ) was used to quantitatively summarize participants level of comfort. Numeric values showed that participants found blockchain to be more understandable and easier to learn by more than one of seven Likert fields after learning about it with the prototypes. They further felt it was more clear, easy, inventive, secure and exciting with each more than one half of a Likert field positive change. In the interviews, blockchains were described to have interesting applications in the future and not needing an intermediary was positively noted while there were only few skeptical remarks.

For the level of abstraction (RQ3) the data showed a number of preferences between visualizations of the same content shown in Table 7.5 and a theme of visuals that are simple and easy to understand at first sight, without many details, conveying only one aspect became apparent. Examples from the interviews that were remembered by participants were a visualization showing how blocks are chained using hashes that are represented as fingerprints (see Figure 7.7) and the hash formula from the game prototype. The consensus mechanism and the Proof of Work and miners were mentioned to have been confusing.

Based on the findings from this work, five recommendations were elaborated. These center around being specific and clear where needed, which is especially the handling of data in blockchains and leaving out details that are unnecessarily confusing. Somewhat of a simplicity regarding the abstraction of contents and visualizations has shown to be beneficial for understanding key elements rather than details for non-experts. Finally, as no significant differences for the learning effect were found in this study, choosing a learning method could be based on the purpose and environment it is meant to be used in.

Limitations of this work include the small number of participants and the demographics of them which is impaired by the fact that they were recruited from a university lecture. A broader range of participants with different occupational backgrounds as well as age and gender should be considered. Cultural differences could play a role as well such as in different countries. This also applies to the experts for the expert interviews, who were all male. Furthermore, the prototypes have a certain design and it is essentially impossible to design anything without making people who experience it feel something towards the artifact and its' thematic contents which is again subjective and depends on personal previous experiences and preference amongst others. This could be dependent on small details in the design such as wording, graphical design, layout, voice, interface interactions or similar. Therefore it would be interesting to see whether the results can be reproduced and confirmed with new prototypes that have a different design. Other learning methods such as graphical illustrations, workshops, more interactive websites or online multiplayer games could be included in future work. The collected data could be analyzed focussing on different aspects for other insights such as on learning preference, gender, age or on each individual knowledge question and studying how the exact answer options change to see what aspects confused participants in more detail. One or more prototypes could be refined and tested again. Perhaps similar studies could be conducted with other technological topics to see whether the insights can be transferred to other fields.

To conclude, this work evaluated three digital prototypes that explain the basics of blockchain technology in an accessible way and language for non-experts. The contents were established from literature, a workshop and expert interviews revealing that especially the handling of data, the main characteristics and applications should be addressed. The results of the user study showed that the prototypes didn't significantly differ in their learning effect on the participants however do have different fields of application as they showed different learning properties. The subjective level of comfort was increased and general impression of blockchain was better after learning about them through the prototypes. Finally, the level of abstraction was found to be most effective when not including many details or otherwise fully explaining what is mentioned. Visualizations that focussed on only one aspect and abstracted the rest were remembered and understood better by participants of the user study. These findings can be used for future applications where the intention is to inform non-experts on blockchain technology, however they may also extend to other technological areas.

List of Figures

List of Tables

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Appendix

Workshop and Expert Interview

How much do you know about the blockchain technology?

	1 - Beginner almost nothing	2	3	4	5 - Expert I learned a lot about it
Number of participants	7	5	2	2	0

Table 1: Participants self-assessment of blockchain knowledge

I was personally involved with blockchain applications (in my professional or personal life)

	Yes	No
Number of participants	4	12
If yes, where? - Trading & Speculations (3 mentions) - Software Development		

Table 2: Participants involvement with blockchain

How much influence do you think blockchain will have on our future and our lives?

	Little influence	No idea	Strong influence
Number of participants	2	4	10

Table 3: Participants assessment of blockchain influence

How interested are you in the topic blockchain?

	1 - not at all	2	3	4	5 - very interested
Number of participants	0	3	7	5	1

Table 4: Participants level of interest for the blockchain technology

Are you actively seeking information on blockchain?

	Yes	Yes and No	No
Number of participants	5	5	6

Table 5: Are participants actively seeking information?

Where have you heard or read about blockchain? Where do you get information from?

	Newspaper, Magazine	Friends, Family	Books	Social Media, Blogs, Websites
Number of participants	**8**	6	1	**10**

	Conferences, Seminars, Webinars	TV	At work	Other
Number of participants	4	5	3	3

Table 6: Where do participants get information on blockchain

Comprehensibility

What is easy to understand? What contributes to good comprehensibility? Attention should be paid to? Wording, length, ...	What is hard to understand and why? What contributes to bad comprehensibility?
	• The text raises many further questions like: - Who is it for? - What is a copy (that everyone has) exactly? - What about privacy? - What does transparency mean? - What is the goal? • The example is too abstract. • Image + Text would be better • Text is partly inconsistent.

Table 7: Participants feedback on the comprehensibility of the presented text.

Level of Detail

Is the level of detail sufficient? What is positively mentionable?	Is there too little or too much information? What needs to be improved?
	• The level of detail is insufficient for understanding and the following questions need to be addressed: - What is a block? - Is the blockchain the product? - What is behind it? - How exactly does it work (examples)? - Which software is required? Internet?

Table 8: Participants feedback on the level of detail of the presented text.

Type of Learning Method

Why does this type of learning method appeal to you? What do you like about it?	Why does this type of learning method not appeal to you? What do you dislike about it?
• Advantages are highlighted in bold (What exactly is the point? - it should result in this)	• Sentences are too long and difficult to understand • Images are missing (e.g. to illustrate transparency visually) • Readers are not addressed directly • Graphical illustrations + text or video/animation would be better • Specific examples are missing (e.g. mobility)

Table 9: Participants feedback on the learning method text.

Comprehensibility

What is easy to understand? What contributes to good comprehensibility? Attention should be paid to? Wording, length, ...	What is hard to understand and why? What contributes to bad comprehensibility?
• Text is easy to understand. • Imagery is good.	• A legend is missing. e.g. who are the parties? • The depiction of the process is still unclear. • Imagery is sometimes unclear. • Text raises more questions: e.g. Does the confirmation happen automatically?

Table 10: Participants feedback on the comprehensibility of the presented graphical illustration.

Level of Detail

Is the level of detail sufficient? What is positively mentionable?	Is there too little or too much information? What needs to be improved?
• Images at the beginning and end are good.	• The breakdown between alteration and transaction - unclear, more information is needed • Majority of involved parties decide - unclear, more information is needed • Graphical illustration of the text barely creates added value • Colors are missing • No information to: What is a block?

Table 11: Participants feedback on the level of detail of the presented graphical illustration.

Type of Learning Method

Why does this type of learning method appeal to you? What do you like about it?	Why does this type of learning method not appeal to you? What do you dislike about it?
	• The example is visually cluttered and messy. • There are more questions: - Why is the process secure when all participants receive all transactions? - Whose device is being used? • Arrows for transaction/process are confusing. • Guiding thread is missing.

Table 12: Participants feedback on the learning method graphical illustration.

Comprehensibility

What is easy to understand? What contributes to good comprehensibility? Attention should be paid to? Wording, length, ...	What is hard to understand and why? What contributes to bad comprehensibility?
• Some participants found the example not too technical, simple and a good example to get started. • Subtitles are convenient (for example when you watch in the subway) • Idea: Getting started video and then a series of subtopics, this way you can decide yourself where you want to learn in more detail. • The best learning method so far • Explanation what a block is and why it has advantages is incorporated.	• Some participants still found the example too technical • Presentation was too fast, one can't follow at some point • Sound quality is not good • Practical application examples are missing • End is confusing • Video raises questions - relation to Bitcoin? - what is mining? - is the information to transactions saved on my computer?

Table 13: Participants feedback on the comprehensibility of the presented video.

Level of Detail

Is the level of detail sufficient? What is positively mentionable?	Is there too little or too much information? What needs to be improved?
• The level of detail is adequate for the length of the video, almost a bit too much.	• For a general understanding it needs significantly more time, information and examples - a higher level of detail and a longer video would therefore be better (important information is still missing; how exactly it works doesn't come across) • Participants could not follow half way through (too fast, can't follow with thoughts) • Information you don't remember is gone after watching the video

Table 14: Participants feedback on the level of detail of the presented video.

Type of Learning Method

Why does this type of learning method appeal to you? What do you like about it?	Why does this type of learning method not appeal to you? What do you dislike about it?
• No background music is pleasant. • Simplistic symbolism (one block is one die) • Animations and dynamic illustrations are good • Animation + voice-over is very positive - better than a video with a speaker (like in tele-shopping) that would appear dubious	• Analogies and specific examples (something familiar from everyday life) are missing. • Resolution is bad. • Analogy with mixer is dubious - gives the impression that everything is being mixed. • The voice: not very enthusiastic

Table 15: Participants feedback on the learning method video.

Expert Interview Leitfaden

- Danke für die Bereitschaft zu diesem Interview, ca 30min
- Consent Form mit kleinem Dankeschön
- Diktiergerät starten

- [Vorstellung von mir und meiner Diplomarbeit]

- Was ist Ihre Rolle in [Projekt/Gruppe, angepasst an Experte]
- Wie denken Sie, wird sich Blockchain für BenutzerInnen im Alltag bemerkbar machen? (abgesehen von Bitcoin, zB im Energiekontext – P2P Trading)
- Wird es überhaupt bemerkbar sein bzw. etwas für sie ändern – nachdem es ja „nur" eine Backend Technologie ist?
- *Was denken Sie ist notwendig, damit sich eine solche Blockchain Anwendung bei KundInnen durchsetzt?*
- Unter anderem wird mangelndes Verständnis für die Technologie von BenutzerInnen als Herausforderung genannt (Literatur, Online). Was ist Ihrer Meinung nach das Problem dabei?
- Haben Sie das schon als Problem erlebt (in Ihren Projekten)? Wie haben Sie das gelöst?
- Was denken Sie, sollten BenutzerInnen unbedingt wissen und warum?
- Gibt es Vorteile / Probleme / Sicherheitsbedenken die BenutzerInnen kennen sollten?
- Welches Wissen denken Sie, ist für BenutzerInnen nicht unbedingt notwendig?
  Wo ist die Grenze? Was ist zu viel? Was kann / sollte man abstrahieren?
- *Inwiefern denken Sie, würden sich BenutzerInnen mit diesem Wissen wohler fühlen? (repeat)*
- Wie sollte ihnen das Ihrer Meinung nach vermittelt werden?
  Mit welchen Methoden? Über welche Kanäle? Worauf muss dabei geachtet werden?
- Wer denken Sie, ist verantwortlich für die Vermittlung dieses Verständnisses an BenutzerInnen und warum?
- *Haben Sie eine konkrete Vorstellung dazu, wie dies umgesetzt werden sollte? Wenn ja, wie?*
- Haben Sie schon konkret Erfahrungen damit gemacht Nicht-ExpertInnen Blockchain zu erklären? Evtl. mit anderen Projekten oder privat? Was waren ihre persönlichen Erkenntnisse daraus?

- Vielen Dank für Ihr Expertenwissen und die Zeit, die Sie sich für mich genommen haben!
  Gibt es noch etwas, das Sie mir mit auf den Weg geben wollen?
  Haben Sie noch Fragen an mich?
- Darf ich ggf. rückfragen, falls beim Durchgehen Unklarheiten zu Ihren Aussagen auftauchen?

Figure 1: Generalized Rough Guideline for Expert Interviews

Video Script

In Zukunft könnten Sie Strom direkt von ihrem Nachbarn mit der Solaranlage kaufen, ohne einem zwischengeschaltenen Energieanbieter, der den Preis angibt. So könnte Ihr Nachbar seinen Überschuss sinnvoll an Sie weitergeben und beide sparen Geld. Aber wie funktioniert das? Mit der Blockchain Technologie.

Von Blockchain haben Sie wahrscheinlich schon gehört, Bitcoin, Mining, Satoshi Nakamoto, Smart Contracts und so weiter. Wie Blockchain funktioniert und wie die Technologie für den direkten Energieaustausch verwendet werden kann, das sehen wir uns jetzt an. Die Blockchain Technologie läuft eigentlich im Hintergrund, sie ist für die Speicherung und von Information verantwortlich. Das bedeutet, dass Sie als BenutzerIn in den meisten Fällen wahrscheinlich wenig von der Technologie selbst mitbekommen, außer Sie möchten das.

Was ist daran jetzt so besonders fragen Sie sich? Die Blockchain ist fälschungssicher, transparent und ermöglicht Transaktionen von Nutzer-zu-Nutzer, von Peer-2-Peer, ohne Mittelsperson als kontrollierenden Faktor. Das bedeutet, es ermöglicht einen sicheren vertrauenswürdigen Datenaustausch für Geschäftsvorgänge direkt zwischen Personen in einem Netzwerk, ohne dass eine Organisation, wie etwa eine Bank oder ein Energieanbieter diese überprüfen muss. Diese Eigenschaften ergeben sich durch die besondere technische Architektur von Blockchain.

Die besondere technische Architektur setzt sich aus einer Kombination der kryptographischen Aneinanderkettung, der Dezentralität und einem Konsens-Mechanismus zusammen. Das ist jetzt viel auf einmal. Also sehen wir uns das mal von Grund auf an. Warum heißt das Block-chain?

Die Blöcke sind die Form der Speicherung im Computer. In einem Block wird also Information aufgeschrieben. Die Blöcke sind kryptographisch aneinandergekettet und bilden eine sichere Informationsquelle, eine Art digitales Grundbuch, das sich besonders für die Abbildung von geschäftlichen Transaktionen eignet. Für einen Energieaustausch würde also drin stehen, wer an wen wie viel Energie verkauft, zu welchem Preis und möglicherweise weitere Details. Bei Bitcoin stehen Geld Überweisungen in den Blöcken.

Die Kette, also die Chain ergibt sich aus der kryptographischen Aneinanderkettung der Blöcke mittels Hashes. In jedem Block ist zusätzlich zu den Daten auch ein Hash enthalten. Einen Hash können Sie sich wie eine Prüfsumme vorstellen, bei einer Prüfsumme wissen Sie, ob in ihrer Rechnung alles enthalten ist, wäre etwas inkorrekt, würde dies bei der Prüfsumme auffallen. So ist das auch bei Hashes, wäre der Inhalt des Blocks manipuliert, würde dies in der Prüfsumme auffallen. Also kann niemand den Inhalt, also den Geschäftsvorgang der im Block gespeichert ist ändern.

Stellen Sie sich einen Hash außerdem auch wie eine Prüfsumme einer sehr langen und komplexen Rechnung vor, sodass es sehr unwahrscheinlich ist, dass eine andere Rechnung dieselbe Prüfsumme ergibt. Denn bei einem Hash wird darauf geachtet, dass er eindeutig zu nur einem Block passt, wie ein Fingerabdruck sozusagen.

Jetzt haben wir aber noch keine Kette. Zusätzlich ist in jedem Block auch der Hash des vorherigen Blocks gespeichert und so weiter. Wenn also ein neuer Block erstellt wird, werden zuerst die Daten und der Hash des vorigen Blocks darin reingeschrieben, und erst dann wird der neue Hash, also die Prüfsumme berechnet. Warum? Dadurch wird eine eindeutige Reihenfolge der Blöcke sichergestellt. Wenn jemand einen Block entfernen oder einen neuen Block einfügen würde, würden die Prüfsummen nicht mehr stimmen. Jetzt haben wir unsere Kette.

Aber wie kann ich damit jetzt Energie direkt mit meinem Nachbarn austauschen fragen Sie sich? Damit das direkt geht, müssen wir noch die "Mittelsperson" als zentrale Anlaufstelle ersetzen. Diese dient oft als vertrauenswürdige Zwischeninstanz zum Speichern und Kontrollieren der Daten. Gründe, warum wir lieber ein System ohne diese wollen, sind beispielsweise wenn wir der Anlaufstelle mit dieser Autorität nicht vertrauen wollen oder können oder wenn diese für ihren Aufwand viel Geld verlangt. Aber wie speichern und kontrollieren wir dann sonst?

Momentan sieht es so aus: Unsere Daten sind bei einer zentralen Instanz, einer Mittelsperson gespeichert. Diese kümmert sich um deren Speicherung und die Abwicklung und Kontrolle von neuen Geschäftsfällen zwischen den Nutzerinnen und Nutzern - also beispielsweise zwischen Ihnen und Ihrem Nachbarn. Mit Blockchain fällt diese Mittelsperson weg. Stattdessen speichern und kontrollieren unsere Computer selbst die Information. Unsere Computer kommunizieren selbstständig miteinander um direkt Geschäftsfälle abzuwickeln. Damit hat niemand mehr besondere Autorität. Jeder von uns stellt einen Knoten in einem Netzwerk dar. Jeder kann überprüfen ob alle Daten korrekt sind. Damit gibt es keine Zentrale, keine Mittelsperson mehr - unsere Daten sind dezentral gespeichert und transparent. Weitere Vorteile der Dezentralität sind, dass es nun noch schwieriger ist, die Daten zu manipulieren, da ein Hacker nun die Blockchain auf jedem Computer ändern müsste.

Wie stellen wir nun sicher, dass jeder dieselbe Version der Blockchain hat? Damit ein neuer Block erstellt werden kann gibt es verschiedene Verfahren um ihn für alle als gültig zu kennzeichnen. Gültig bedeutet, dass der Inhalt, also die abgebildeten Geschäftsfälle überprüft wurden und er einen korrekten Hash besitzt. Das wird von jedem Knoten im Netzwerk überprüft und dann an die eigene lokale Blockchain angehängt. Dabei wird ein Konsens geschaffen, das heißt wird der Block von mehr als der Hälfte der Knoten abgelehnt, dann wird der Block verworfen. Wird er von mehr als der Hälfte der Knoten angenommen, hängen alle diesen Block bei sich an.

Wie und von wem werden Blöcke nun erstellt? Woran erkennt mein Computer, ob diese gültig sind? Bei Bitcoin übernehmen das die Miner, vielleicht haben Sie diesen Begriff schon gehört. Die sogenannten Miner erbringen dort einen Arbeitsnachweis, den sogenannten Proof-of-Work. Dieser Proof-of-Work ist im Prinzip nichts anderes als eine künstliche Verlangsamung der Prüfsummen-, also Hash Berechnung durch das Einfügen einer Zufallskomponente die ein Miner durch ausprobieren "erraten" muss. Die Miner stehen im Wettbewerb zueinander denn der Miner, der dies zuerst errät und an alle anderen schickt, bekommt eine finanzielle Belohnung. Im Prinzip kann jeder Teilnehmer des Netzwerkes Miner sein. Durch den Wettbewerb nutzen Miner allerdings spezielle Hardware die über mehr Rechenleistung verfügen um am schnellsten zu sein. Bitcoin garantiert dass immer Rechenleistung und Zeit benötigt wird um Blöcke zu erstellen.

Eine unbefugte Person, wie ein Hacker, müsste nun, wenn er etwas in der Blockchain manipulieren möchte, die Hashes aller darauf folgenden Blöcke ebenso neu berechnen – das ist eine Menge Proof-of-Work die dies zeitlich praktisch unmöglich macht. Dann müsste er die manipulierte Version auch an über 50% der Netzwerkcomputer verteilen.

Die Nachteile davon sind der hohe Energieverbrauch und dass Miner mit viel Hardware sozusagen an Macht gewinnen. Und das wollten wir ja verhindern.

Es gibt aber auch andere Varianten um die Gültigkeit neuer Blöcke zu garantieren. Gibt es beispielsweise eine Person oder Instanz im Netzwerk dessen Vertrauenswürdigkeit nachgewiesen werden kann, so kann diese die Blöcke kontrollieren und sie mit einer digitalen Unterschrift signieren. So sehen alle, dass der Block von einer vertrauenswürdigen Quelle ist und fügen ihn bei sich ein. Das nennt sich Proof-of-Authority.

Eine andere Alternative ist ein Beteiligungsnachweis, der als Proof-of-Stake bezeichnet wird. Hier wählt ein Algorithmus jemanden für die Erstellung des nächsten Blocks aus. Dieser Algorithmus wählt aus den Nutzern mit den höchsten Anteilen nach dem Zufallsprinzip aus. Der Gedanke dabei ist, dass stark beteiligte Nutzer Interesse an der korrekten Abwicklung von Transaktionen haben. Proof-of-Stake und Proof-of-Authority ermöglichen beide eine rasche und effiziente Bearbeitung von neuen Blöcken, verfügen allerdings ebenso über Nachteile, da sie von der Vertrauenswürdigkeit bestimmter Nodes ausgehen.

Sie denken sich vielleicht gerade, dass Sie doch gar nicht wollen, dass jeder Ihre Geschäftsvorgänge im Netzwerk sieht bzw. kontrolliert? Blockchains können diesbezüglich unterschiedlich gestaltet werden. Meist sind die Daten verschlüsselt und so zwar für alle sichtbar, jedoch nicht unbedingt sinnvoll lesbar. Zur Überprüfung der Geschäftsvorgänge werden meist eindeutige Identifikationsnummern verwendet, das heißt im Block ist zum Beispiel gespeichert, dass A an B Strom verkaufen möchte. Das Netzwerk kann nun überprüfen ob A diesen Strom hat, und ob B diesen bezahlen kann. Jedoch können sie nicht zwangsweise zuordnen, dass die ID A zu Frau Müller gehört.

Was, wenn ich aussteigen möchte? Kann ich meine Daten löschen? Nein, das funktioniert auf der Blockchain leider nicht. Jedoch können Sie die Zuordnung von Ihrer ID zu Ihrer Person aus dem System entfernen lassen. Die Transaktionen bleiben allerdings trotzdem in der Kette erhalten. So, jetzt sind wir die wichtigsten Eigenschaften von Blockchains durchgegangen.

Die wichtigsten Vorteile nochmal zusammengefasst: Blockchain ermöglicht den sicheren Informationsaustausch direkt zwischen Personen (bzw. deren Computer) ohne zentraler vertrauenswürdiger Autorität, die Daten auf der Blockchain sind außerdem fälschungssicher unveränderlich, nicht löschbar, transparent und dezentral gespeichert. Daraus können sich auch Nachteile ergeben wie typischerweise Effizienz, Skalierbarkeit auf große Netzwerke mit vielen Informationsaustauschen und Energieverbrauch. Außerdem sind Blockchains im Vergleich zu üblichen Methoden noch relativ neu und unerprobt.

Es gibt jedoch einige verschiedene Arten, auch abgesehen vom Finanzmarkt und Bitcoin wie und wo Blockchains angewandt werden können und oft ergeben sich dadurch unterschiedliche Vor- und Nachteile. Im Energiebereich etwa, wenn Sie von ihren Nachbarn Strom kaufen wollen, müssen Transaktion schnell und billig gehalten werden, da sich das sonst nicht lohnen würde. Welche Anwendungen und Varianten vielleicht sonst noch für Blockchain erfunden werden - bleiben wir gespannt.

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User Study

The following pages show the original pre- and post questionnaires and interview guideline, that were used in the user study in German language.

TN-Kennzahl

Pre-Fragebogen

Teil 1:

Wie alt sind Sie? ____________

Was ist Ihr Geschlecht? ☐ weiblich ☐ männlich ☐ ____________

Was ist Ihre höchste abgeschlossene Ausbildung?

☐ Grundschule
☐ Hauptschulabschluss
☐ Realschulabschluss bzw. Mittlere Reife
☐ Matura
☐ Bachelor
☐ Master bzw. Magister
☐ Diplom
☐ Promotion

Welchen fachlichen / beruflichen Hintergrund haben Sie?

____

Sind Sie mit Blockchain schon in Berührung gekommen? Falls ja, in welchem Kontext?

____

Welche Einsatzmöglichkeiten von Blockchain können Sie sich im Energiebereich vorstellen?

____

Wie schätzen Sie Ihr Wissen zu Blockchain ein?

1 – Anfänger (kaum Wissen)	2	3	4	5 – Experte (intensiv damit beschäftigt)
☐	☐	☐	☐	☐

Fassen Sie bitte in wenigen Worten zusammen, was Sie über Blockchain wissen.
Was ist Blockchain? Wie funktioniert Blockchain?

____

____

____

Mit welchen Medien lernen Sie am liebsten und effizientesten?

- ☐ Vorträge, Konferenzen, Seminare, Vorlesungen
- ☐ Bücher
- ☐ TV, Dokumentationen
- ☐ Soziale Medien, Blogs
- ☐ Websites
- ☐ Erklärungsvideos (zB YouTube)
- ☐ Lernspiele

Haben Sie schon Erfahrung damit gemacht aus Websites zu lernen?
Falls ja, wie hat das für Sie funktioniert?

____

____

Haben Sie schon Erfahrung damit gemacht aus Erklärungsvideos (zB YouTube) zu lernen?
Falls ja, wie hat das für Sie funktioniert?

____

____

Haben Sie schon Erfahrung damit gemacht mit Lernspielen zu lernen?
Falls ja, wie hat das für Sie funktioniert?

____

____

TN-Kennzahl

Teil 2 -- Momentaufnahme Vorwissen:

Was ist eine Blockchain?

- ☐ Eine Variante der Kryptowährung
- ☐ Ein verteilter Datenspeicher in einem Netzwerk von BenutzerInnen
- ☐ Ein zentraler Datenspeicher für den Austausch von Werten zwischen BenutzerInnen

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Welche der folgenden Elemente werden in der Blockchain-Technologie verwendet?

- ☐ Kryptographische Aneinanderkettung
- ☐ Dezentralität
- ☐ Konsens-Mechanismus

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Was ist ein Block?

- ☐ Ein Block beinhaltet Daten des Blockchain-Netzwerkes.
- ☐ Ein Block bezeichnet eine Gruppe an NutzerInnen im Blockchain-Netzwerk.
- ☐ Ein Block ist ein Benutzerkonto innerhalb des Blockchain-Netzwerkes.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Welche der folgenden Elemente sind in jedem Block enthalten?

- ☐ Eine Hash-Identifikation des vorherigen Blocks.
- ☐ Eine Hash-Identifikation des nächsten Blocks.
- ☐ Eine Transaktion.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Wie sind Blöcke in einer Blockchain verlinkt?

- ☐ Mehrfach untereinander
- ☐ Rückwärts zum vorherigen Block
- ☐ Vorwärts zum nächsten Block

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

TN-Kennzahl

Was ist eine Transaktion?

☐ Eine Transaktion repräsentiert den Transfer von Werten von einem Besitzer zu einem anderen Besitzer.
☐ Eine Transaktion ist ein Geschäftsfall, bei welchem große Besitztümer gewechselt werden.
☐ Transaktionen haben mit Blockchain nichts zu tun.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Wo ist die Blockchain gespeichert?

☐ Auf einem zentralen Server in London, England.
☐ Auf einem zentralen Server der Betreiberfirma im jeweiligen Land.
☐ Auf jedem teilnehmenden Computer des Blockchain-Netzwerkes.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Wie werden die Daten auf der Blockchain gespeichert?

☐ In einer Liste von Blöcken, die mittels Hashes verbunden sind. Der Hash eines Blockes verifiziert die Integrität (Richtigkeit) des vorherigen Blocks.
☐ In einer relationalen Datenbank, die die Daten in Konten in Form von Tabellen abspeichert. Mittels Identifikationsnummern können die Konten eindeutig verbunden werden.
☐ In einem Netzwerk von Blöcken die mittels Kryptographie mehrfach untereinander vernetzt sind. Die Blöcke sind jeweils mit mehreren nachfolgenden Kind-Blöcken verbunden.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Wozu dient der Konsens-Mechanismus?

☐ Dazu, dass alle NutzerInnen im Netzwerk der Richtigkeit der Daten vertrauen können
☐ Dazu, die kontrollierende zentrale Mittelsperson zu ersetzen
☐ Dazu, die Daten am zentralen Speicherort zu kontrollieren

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Können Daten nachträglich, nachdem sie in der Blockchain eingefügt wurden, geändert werden?

☐ Ja, die Beteiligten können jederzeit einsehen und Daten ändern.
☐ Ja, jedoch nur innerhalb eines bestimmten Zeitraumes.
☐ Nein, sie können nicht mehr gelöscht, sondern lediglich anonymisiert werden.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

TN-Kennzahl

Pre-Fragebogen Blockchain – die Technologie erklärt

Teil 3 – Momentaufnahme Eindruck:

Wie wohl würden Sie sich dabei fühlen, eine Anwendung, welche Daten mittels einer Blockchain speichert und austauscht zu nutzen?

1 – sehr unwohl	2	3	4	5 – sehr wohl
☐	☐	☐	☐	☐

Welchen Eindruck haben Sie von Blockchain?

Bitte entscheiden Sie sich möglichst spontan. Es ist wichtig, dass Sie nicht lange über die Begriffe nachdenken, damit Ihre unmittelbare Einschätzung zum Tragen kommt. Bitte kreuzen Sie immer nur einen Kreis pro Zeile an, auch wenn Sie bei der Einschätzung zu einem Begriffspaar unsicher sind oder finden, dass es nicht passend ist.
Es gibt keine „richtige" oder „falsche" Antwort. Ihre persönliche Meinung zählt!

	1	2	3	4	5	6	7	
langweilig	○	○	○	○	○	○	○	spannend
unverständlich	○	○	○	○	○	○	○	verständlich
originell	○	○	○	○	○	○	○	konventionell
uninteressant	○	○	○	○	○	○	○	interessant
behindernd	○	○	○	○	○	○	○	unterstützend
gut	○	○	○	○	○	○	○	schlecht
abstoßend	○	○	○	○	○	○	○	anziehend
herkömmlich	○	○	○	○	○	○	○	neuartig
sicher	○	○	○	○	○	○	○	unsicher
kompliziert	○	○	○	○	○	○	○	einfach
aktivierend	○	○	○	○	○	○	○	einschläfernd
übersichtlich	○	○	○	○	○	○	○	verwirrend
unangenehm	○	○	○	○	○	○	○	angenehm
attraktiv	○	○	○	○	○	○	○	unattraktiv
sympathisch	○	○	○	○	○	○	○	unsympathisch
leicht zu lernen	○	○	○	○	○	○	○	schwer zu lernen
konservativ	○	○	○	○	○	○	○	innovativ

Figure 2: Pre-Questionnaire

TN-Kennzahl

Post-Fragebogen

Teil 1 – Momentaufnahme Wissen:

Was ist eine Blockchain?

- ☐ Eine Variante der Kryptowährung
- ☐ Ein verteilter Datenspeicher in einem Netzwerk von BenutzerInnen
- ☐ Ein zentraler Datenspeicher für den Austausch von Werten zwischen BenutzerInnen

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Welche der folgenden Elemente werden in der Blockchain-Technologie verwendet?

- ☐ Kryptographische Aneinanderkettung
- ☐ Dezentralität
- ☐ Konsens-Mechanismus

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Was ist ein Block?

- ☐ Ein Block beinhaltet Daten des Blockchain-Netzwerkes.
- ☐ Ein Block bezeichnet eine Gruppe an NutzerInnen im Blockchain-Netzwerk.
- ☐ Ein Block ist ein Benutzerkonto innerhalb des Blockchain-Netzwerkes.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Welche der folgenden Elemente sind in jedem Block enthalten?

- ☐ Eine Hash-Identifikation des vorherigen Blocks.
- ☐ Eine Hash-Identifikation des nächsten Blocks.
- ☐ Eine Transaktion.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Wie sind Blöcke in einer Blockchain verlinkt?

- ☐ Mehrfach untereinander
- ☐ Rückwärts zum vorherigen Block
- ☐ Vorwärts zum nächsten Block

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Was ist eine Transaktion?

☐ Eine Transaktion repräsentiert den Transfer von Werten von einem Besitzer zu einem anderen Besitzer.
☐ Eine Transaktion ist ein Geschäftsfall, bei welchem große Besitztümer gewechselt werden.
☐ Transaktionen haben mit Blockchain nichts zu tun.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Wo ist die Blockchain gespeichert?

☐ Auf einem zentralen Server in London, England.
☐ Auf einem zentralen Server der Betreiberfirma im jeweiligen Land.
☐ Auf jedem teilnehmenden Computer des Blockchain-Netzwerkes.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Wie werden die Daten auf der Blockchain gespeichert?

☐ In einer Liste von Blöcken, die mittels Hashes verbunden sind. Der Hash eines Blockes verifiziert die Integrität (Richtigkeit) des vorherigen Blocks.
☐ In einer relationalen Datenbank, die die Daten in Konten in Form von Tabellen abspeichert. Mittels Identifikationsnummern können die Konten eindeutig verbunden werden.
☐ In einem Netzwerk von Blöcken die mittels Kryptographie mehrfach untereinander vernetzt sind. Die Blöcke sind jeweils mit mehreren nachfolgenden Kind-Blöcken verbunden.

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Wozu dient der Konsens-Mechanismus?

☐ Dazu, dass alle NutzerInnen im Netzwerk der Richtigkeit der Daten vertrauen können
☐ Dazu, die kontrollierende zentrale Mittelsperson zu ersetzen
☐ Dazu, die Daten am zentralen Speicherort zu kontrollieren

Wie sicher sind Sie sich?

1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

Können Daten nachträglich, nachdem sie in der Blockchain eingefügt wurden, geändert werden?

☐ Ja, die Beteiligten können jederzeit einsehen und Daten ändern.
☐ Ja, jedoch nur innerhalb eines bestimmten Zeitraumes.
☐ Nein, sie können nicht mehr gelöscht, sondern lediglich anonymisiert werden.

Wie sicher sind Sie sich?

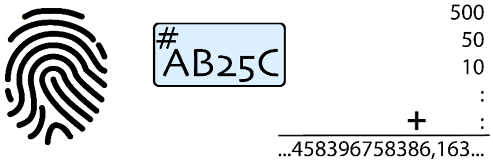
1 – ich habe geraten	2	3	4	5 – sehr sicher
☐	☐	☐	☐	☐

TN-Kennzahl

Teil 2 – Präferenz Abstraktionen:

Wählen Sie in den folgenden Fragen bitte welche der Analogien Ihnen am besten beim Verständnis der jeweiligen Konzepte geholfen hat.

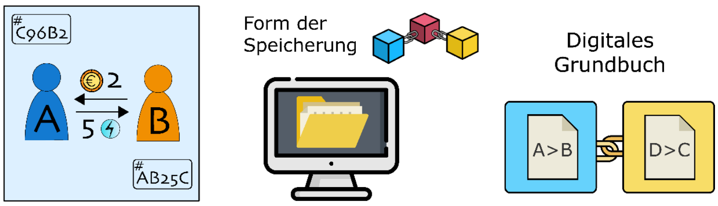
Ich habe das Konzept von einem Hash am besten verstanden mit der Analogie von:



- ☐ einem digitalem Fingerabdruck (links)
- ☐ einer kryptographischen Identifikation, die mit einer Formel errechnet wird (mittig)
- ☐ einer komplexen Prüfsumme (rechts)
- ☐ keine der obigen, einfachere Analogien wären besser
- ☐ keine der obigen, mehr Details wären besser

Falls keine der obigen Darstellungen, skizzieren Sie bitte, welche Darstellung Ihnen helfen würde:

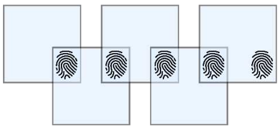
Ich habe das Konzept von einem Block am besten verstanden mit dieser Analogie:

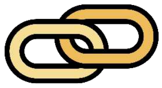


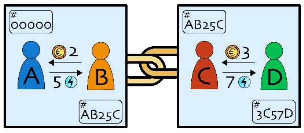
- ☐ bildlich dargestellt (links)
- ☐ beschrieben als Form der Speicherung im Computer (mittig)
- ☐ zusammengehängt ergeben Blöcke ein „digitales Grundbuch“ für Geschäftsfälle (rechts)
- ☐ keine der obigen, einfachere Analogien wären besser
- ☐ keine der obigen, mehr Details wären besser

Falls keine der obigen Darstellungen, skizzieren Sie bitte, welche Darstellung Ihnen helfen würde:

Ich habe das Konzept von der Aneinanderkettung am besten verstanden mit der Analogie:



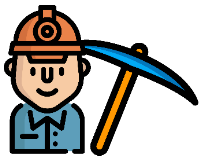




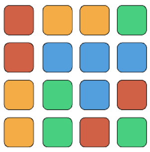
☐ Überlappende Blöcke mit Fingerabdruck (links)
☐ Kettensymbol (mittig)
☐ Hash-Codes, welche die Blöcke verbinden (rechts)
☐ keine der obigen, einfachere Analogien wären besser
☐ keine der obigen, mehr Details wären besser

Falls keine der obigen Darstellungen, skizzieren Sie bitte, welche Darstellung Ihnen helfen würde:

Ich habe das Konzept von Proof of Work am besten verstanden mit der Analogie:



~10min
Proof of Work



☐ Minenarbeiter, die mit Werkzeug schwer arbeiten (links)
☐ Sanduhr die zeigt, dass es eine gewisse Zeit braucht (mittig)
☐ Rätsel, das durch Ausprobieren gelöst wird (rechts)
☐ keine der obigen, einfachere Analogien wären besser
☐ keine der obigen, mehr Details wären besser

Falls keine der obigen Darstellungen, skizzieren Sie bitte, welche Darstellung Ihnen helfen würde:

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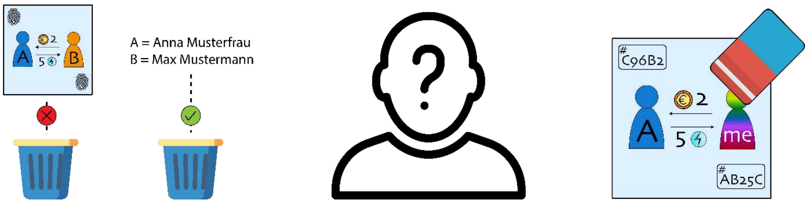
Ich habe das Konzept vom Datenlöschen in der Blockchain am besten verstanden mit der Analogie:



☐ Zuordnung zB A = Anna Musterfrau, welche gelöscht wird (links)
☐ Anonymisierung (mittig)
☐ Namen wegradieren, während Blöcke erhalten bleiben (rechts)
☐ keine der obigen, einfachere Analogien wären besser
☐ keine der obigen, mehr Details wären besser

Falls keine der obigen Darstellungen, skizzieren Sie bitte, welche Darstellung Ihnen helfen würde:

TN-Kennzahl

Post-Fragebogen — Blockchain – die Technologie erklärt

Teil 3 – Momentaufnahme Eindruck:

Fanden Sie die Information zu Blockchain nützlich?

1 – nicht nützlich	2	3	4	5 – sehr nützlich
☐	☐	☐	☐	☐

Interessieren Sie sich jetzt mehr oder weniger für Blockchain?

1 – weniger	2	3 – gleich	4	5 – mehr
☐	☐	☐	☐	☐

Wie wohl würden Sie sich dabei fühlen, eine Anwendung, welche Daten mittels einer Blockchain speichert und austauscht zu nutzen?

1 – sehr unwohl	2	3	4	5 – sehr wohl
☐	☐	☐	☐	☐

Welchen Eindruck haben Sie von Blockchain?

Bitte entscheiden Sie sich möglichst spontan. Es ist wichtig, dass Sie nicht lange über die Begriffe nachdenken, damit Ihre unmittelbare Einschätzung zum Tragen kommt. Bitte kreuzen Sie immer nur einen Kreis pro Zeile an, auch wenn Sie bei der Einschätzung zu einem Begriffspaar unsicher sind oder finden, dass es nicht passend ist.
Es gibt keine „richtige“ oder „falsche“ Antwort. Ihre persönliche Meinung zählt!

	1	2	3	4	5	6	7	
langweilig	○	○	○	○	○	○	○	spannend
unverständlich	○	○	○	○	○	○	○	verständlich
originell	○	○	○	○	○	○	○	konventionell
uninteressant	○	○	○	○	○	○	○	interessant
behindernd	○	○	○	○	○	○	○	unterstützend
gut	○	○	○	○	○	○	○	schlecht
abstoßend	○	○	○	○	○	○	○	anziehend
herkömmlich	○	○	○	○	○	○	○	neuartig
sicher	○	○	○	○	○	○	○	unsicher
kompliziert	○	○	○	○	○	○	○	einfach
aktivierend	○	○	○	○	○	○	○	einschläfernd
übersichtlich	○	○	○	○	○	○	○	verwirrend
unangenehm	○	○	○	○	○	○	○	angenehm
attraktiv	○	○	○	○	○	○	○	unattraktiv
sympathisch	○	○	○	○	○	○	○	unsympathisch
leicht zu lernen	○	○	○	○	○	○	○	schwer zu lernen
konservativ	○	○	○	○	○	○	○	innovativ

Figure 3: Post-Questionnaire

TN-Kennzahl: ________

Abschlussgespräch

Blockchain-Eindruck

Was ist Ihr Eindruck zu Blockchain? Was dachten Sie vorher? Was jetzt?

Wie stehen Sie dazu, eine Anwendung zu verwenden, von der Sie wissen, dass sie Blockchain zum Datenaustausch einsetzt?	
Was verunsichert Sie?	Was motiviert Sie?

Lernmethoden-Präferenz

Welche Lernmethode hat Ihnen am besten gefallen? Warum? Ranking? Wo fühlen Sie sich am sichersten / wohlsten?

Für welchen Zweck finden Sie welche Methode besser? Spiel, Video, Website? Welcher Kanal? Von welchem Anbieter seriös? In welchem Kontext verwenden?

Welche Methode denken Sie, erzielt den größten Lerneffekt? Warum?

Mit welchen Medien lernen Sie am liebsten / effizientesten? (vgl Pre-Test)

TN-Kennzahl: ________

Was ist (nicht) gut verständlich? Positiv/Negativ an Art der Darstellung?
Detaillierungsgrad ausreichend? Zu hoch/niedrig?

Welche Eigenschaften am **Spiel** finden Sie ….

Positiv	Negativ
Was muss am Spiel verbessert werden? Wie könnte es besser bzw. mehr Inhalte vermitteln? Wie wäre es herausfordernder? (zB Multiplayer?)	

Welche Eigenschaften am **Video** finden Sie ….

Positiv	Negativ
Was würden Sie am Video verbessern?	

Welche Eigenschaften an der **Website** finden Sie ….

Positiv	Negativ
Was würden Sie an der Website verbessern?	

TN-Kennzahl: ________

Abstraktion

Welche Inhalte waren für sie… (evtl. mit Blick auf MC-Fragen)

Einfach zu verstehen?	Schwierig zu verstehen?
Warum? Was war verwirrend? Formulierung? Animation? Bilder? Spiel?	

Feedback zur Studie

Gibt es etwas, das für Sie während der Studie unangenehm war? Was hätte man besser gestalten können? Hätten Sie mehr / weniger Zeit gebraucht? Haben Sie sonstiges Feedback?

Figure 4: Closing Interview