The Role of Mediums

in Distributed Learning

by

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ABSTRACT

The advancement of technology has transformed information consumption into an accessible and flexible process. The open learning ecosystem that exists online relies on self-direction. Learners are able to effectively fulfill personal learning goals with preferred content forms, specifically by utilizing Massive Open Online Courses (MOOC). It is essential to investigate the role of mediums in distributed learning to initiate human-centric design changes that best support the learner. This study provides insight into how choice influences self-learning and highlights the major engagement difficulties of MOOCs. Significant attrition was experienced while issuing text and audio material to participants for three weeks. Although this prevented valid statistical tests from being run, it was clear that text was the most desirable and effective medium. Students that read exhibited the highest comprehension levels and selected it as their de-facto consumption method even if audio was made available. Since this study involved complex topics, this supported the transient information effect. Future studies should focus deeply on the structure of online courses by implementing personable engagement features that improve overall participation rate.

DEDICATION

I dedicate this to my unconditionally loving parents. Even when my confidence would waver, they encouraged me to keep pushing toward the finish line. Without their unwavering support, I would not be where I am today! Their belief in even my wildest ideas continues to help me overcome any obstacle in my way.

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Introduction

The Internet has continued to grow, enhancing our ability to globally source and disperse information. This accessibility has been furthered through the introduction of smartphones. Individuals are able to readily access a robust repository of information from a variety of sources. As a result, an unconfined and open learning environment has been created. In this interconnected ecosystem, significant educational resources can be sourced in order to facilitate learning. This is represented by a wide range of content modalities that are extremely diverse in content and structure.

This diversity is a direct byproduct of the vastness of the Internet. Content exists in a variety of forms, all seeking to uniquely engage their audience. The selection process is popularly self-driven and dependent on individualistic learning goals. People are drawn to courses that provide them with the best engagement and comprehension. Therefore, it is essential to observe distributed learning consumption habits to best understand how to attract and retain learners. This study uses the popularity of distributed learning as a foundation to explore the role of medium, specifically text and audio, on learning comprehension and engagement.

Growth of the Internet

Januszewski and Molenda (2013) describe how educational technology has developed in a series of phases alongside technological innovations. Beginning as visual and audiovisual systems, it has transformed as communication has changed shape. Information access has become more democratized, progressing from radio to connected mobile devices. The modern-day internet has shaped information processing and storage, drastically impacting daily life patterns at a global scale. It has introduced a digital ecosystem where widespread interactions are more frequent and information is readily available. This level of interconnectedness allows for an exchange of ideas and forms a new habit for wide-scale consumption of content from a variety of sources. The diversity of information present online is represented by various modalities including text, audio and video. Significant online resources and the consistent desire to learn for personal gain have facilitated the creation of an open learning environment. As of today, mobile learning is a convenient and integral learning method. Understanding how connectivity infrastructure has transformed over time is essential for framing the role of mediums in online learning.

Technological advancements of the internet have boosted the reach of the Internet, providing improved access to global information. Economic growth has intensely influenced the location and scale of its saturation. Enriquez et al (2015) describe the digital space as a self-fed system of growth. The Internet allows for greater innovation and therefore, a significant increase in economic throughput. The rise of a nation's gross domestic product (GDP) allows for greater investment flexibility that can be directed towards digital improvements and connectivity infrastructure advancements. The mutualistic relationship shared by innovation and the Internet has contributed to a surge in population with online access, leading to an incremental rise in learning opportunities. Individuals are able to access knowledge that would otherwise be unattainable with only a few clicks. The open learning environment afforded by the Internet continues to support an overwhelming desire to learn and grow.

Growth of Smartphones

The Internet began as a tool reliant on bulky desktop machines for access. This restricted the flexibility and ease of consuming information. Over time, software and hardware accelerated to create small computer no bigger than the size of a pocket. Mobile internet connections rose from 200 million in 2008 to 2.2 billion in 2015 (Enriquez et al., 2015). Smartphones have been rapidly adopted for their flexible usage, transforming how global information is accessed. Learners are able to easily source and consume applicable in patterns that fit their lifestyle. The ability to specifically tailor the learning process makes smartphones a powerful tool. Although, the ability to access information anytime, anywhere using smartphones has transformed daily routines.

It is clear that mobile devices have altered how and where learning is performed. Smartphones have altered the daily movement and mobility patterns of individuals (Birenboim & Shoval, 2016). They serve as mobile computers, allowing for consistent connection to a robust repository of knowledge. Therefore, individuals are able to move freely without fear of losing the immediate access to the world wide web. Traxler (2007) describes how mobile device use engages learners in self-directed habits and stimulates their cognitive curiosity outside of the classroom. Smartphones have directly contributed to the evident shift towards a reliance on mobility and the creation of new engagement tendencies. Information can be accessed from anywhere during a point of need. Smartphones have not only enhanced the role engagement plays in mobile learning, but have also facilitated the growth and extension of a global learning ecosystem.

An Open Learning Ecosystem

The expansion of the Internet, and the portable tools created to access it, have drastically advanced over time. These developments have contributed to a shift from passive to active user engagement (Conole, 2013). Educational resources have grown in diversity, size and accessibility. Additionally, online communities have been born to more easily exchange knowledge. An open and choice-based online learning ecosystem allows for vastly different motivations and meanings for interactions. The high prevalence of choice has resulted in the creation of online courses that seek to fulfill learning pathways. Massive open online courses (MOOC) aim to educate at a large scale through self-paced and interactive participation via the web (Conole, 2016). This is an important push towards democratizing learning using distribution that reduces the friction normally associated with reaching learners. Although, MOOCs continue to suffer from high attrition rates due to poor engagement (Rai & Chunrao, 2016). Investigating how individuals interact with these courses will provide insight necessary to make structural changes meant to retain participants.

Choice remains an integral component to the existence of an open learning environment and fuels self-directed learning. This learning environment is supported by the constructivist learning theory, a process in which individuals construct knowledge and meaning from their experiences (Fosnot & Perry, 1996). This requires active and self-directed learning as means to discovery. Hannafin et al. (2013) pinpoint that constructivist-inspired views of learning are the foundation for the open learning framework that exists today. Students craft a plan for learning after identifying and assigning particular meaning and goals. They are able to learn in the sequence they desire, continually building upon what has already been learned. This self-initiated learning is made possible by the current online system, an environment where information can be accessed with little to no entry barriers.

The Internet provides access to information at scale. Learners are able to shape and fulfill their diverse learning goals with uniquely designed material. Self-directed learning is convenient and has the potential to be more effective in mastering concepts than traditional methods. Zhang et al. (2018) tested the comprehension of diagnostic imaging with two groups of physician assistant students. One group received traditional didactic lectures and the other self-learning computer modules. The results of an identical test given to both groups showed the population with self-learning modules achieved higher grades both on the test and for their overall grade. Self-learning modules had a positive effective on student mastery, as reflected in a better grade. This study showed that online self-study modules can be highly effective teaching tools if designed correctly. Understanding the effectiveness of self-directed learning provides foundation and context for further exploring it in an online environment.

The Internet is not only the backbone of technological advances, but acts as a knowledge base that nearly anyone can access. Topic-focused, on-demand information promotes self-learning endeavors (Haag & Berking, 2014). Diverse information exists in a variety of mediums that can be freely selected. Depending on complexity and readability, content is not always easily understood by a non-expert audience. For example, blockchain technology is a complex topic that few understand well. The educational material of this space is commonly geared toward a technical audience. This is a prevalent hurdle that deeply impacts the attrition rates of MOOCs. Complexity continues to play a major role in how engagement occurs. Identifying how to minimize technicality while preserving clarity is important to solving the educational challenges of distributed learning.

Technological advancements have transformed the ability to learn, but also provided new challenges for manufacturing effective learning environments. The open learning ecosystem contains various content forms, such as text and audio, that require choice to facilitate learning. Prompted by a self-directed desire to further personal goals, this information is accessed by connected devices, especially those that provide mobility. Investigating the impact of content form and presentation, specifically for text and audio, is essential to determining educational frameworks that adequately fit a diverse population spread across the globe.

Choosing a Medium to Learn

The Internet exists as a robust information repository that is organized into an open, online learning ecosystem. Individuals obtain and digest content in a variety of forms in order to facilitate learning. Inside, text and audio persist as major ways to disperse information at a large scale. Increased accessibility of information in text and audio form provides flexible learning options for a variety of individuals. They are able to choose the material that will fulfill their learning goals and lead to the construction of new knowledge.

The basic comprehension process of each medium conveys how to properly design instructional material for a novice learner. Designing properly with user motivations in mind, the recipient can more easily construct knowledge by making inferences from cohesive material. In order to understand how choice plays a role in the learning process, the basic comprehension processes and proper design elements for reading and listening and must be understood.

Learning by reading. Reading is a historically-popular method for constructing knowledge and storing it in the mental schema. The availability and form of text information has drastically enhanced alongside the growth of the internet and smartphones. Online text can be consumed anytime, anywhere and its static form allows for efficient review. Similar to other mediums, an appropriate text-based learning environment should allow the reader to easily form inferences using prior knowledge. Investigating the facets of the text comprehension process will provide valuable insight on how to design readable text.

Text comprehension process. While reading, an individual consumes information to construct new knowledge. Comprehension must be successful for this to occur. The text comprehension process is not momentary. Gill (2008) describes how the mental representation reading provides is long-lasting. It begins to form before reading and continues to be refined after reading is finished. This is beneficial for learning since comprehension is an active operation that benefits from a medium that can be consistently reviewed.

The constructivist theory of learning describes how learning is performed. Dixon-Krauss (1996) suggests readers construct meaning by making connections between the text and their prior knowledge. A reader approaches text with knowledge stored in a mental schema as a result of past experiences. While reading, new information is filtered through existing knowledge and experiences (Haag & Berking, 2014). Doing so highlights knowledge gaps that are specific to the individual's background knowledge. These absences require additional cognitive resources to create uniform understanding. Inferences are utilized in order to close these gaps and assign meaning to the conveyed information. If inferences are explicit, the reader is able to fill gaps in understanding using little of their own knowledge for the topic (Benjamin, 2011). Minimizing inferences allows the reader to more effectively comprehend a passage of text.

This decrease in cognitive load requires less effort to construct new knowledge. Novice learners benefit the greatest from a decrease in cognitive load due to decreased comprehension requirements (Benjamin, 2011). If comprehension is unsuccessful, an individual will reread or consult outside sources to gain a complete understanding. The ability to easily review material is specific to the static nature of text. Individuals are able to review material without drastically disrupting their pattern of engagement. This ensures a streamlined learning process where inferences can be made efficiently.

In practicality, it is extremely common for reading to be performed as an isolated action. Since text exists visually, it requires full attention in order to properly read and comprehend. Sweller (2011) explains the visual channel as being susceptible to overload due to its limited processing capacity. The greater cognitive resources required of non-expert learners will result in comprehension breakdown. Since readers are subject to a high cognitive load, the frequency and complexity of inferences should be reduced. Doing this will increase the chance an individual has to successfully comprehend text material.

Designing readable text. The construction of new knowledge is dependent upon levels of understanding. If a text is readable, then it will be engaging and understood. Proper instructional design of text relies on readability principles rooted in how comprehension occurs. Analogical ties and cohesive structuring are particular design elements of highly readable text.

In order to reduce gaps in understanding, inferences are made using background knowledge. Although, activation of this knowledge is not always a binary process. In support of the general schema activation hypothesis, attaching familiarity to a particular topic allows for the more efficient acquisition of information. Analogies prompt the reader to use well-known similarities to enhance their understanding. Pearson (1983) recommends the use of analogical ties between familiar and unfamiliar domains in order to effectively build background knowledge. This conclusion is supported by a study performed by Hayes and Tierney (1982) in which grouped participants read a single text with explicit analogies between baseball and cricket and texts that independently discussed the sports. The goal was to determine if supplying information about a familiar sport, baseball, would enhance understanding for cricket. The inferential abilities of participants with access to the single text were better as reflected in a greater comprehension of cricket-related information. Therefore, an attempt to supplement background knowledge using analogical ties is superior to discussing irrelevant experiences in text material.

It is clear that inferential skills are dependent on background knowledge. Specificity plays an important role in properly activating background knowledge. Analogical ties must be shaped specifically for the target audience. Without specificity, analogies may not have their intended effect. Actions like background research and pre-tests allow writers to determine topics of interest and a baseline understanding. With this information, effective analogical ties can be integrated into text, improving comprehension through the reduction of inferences.

If used in a high degree, inference can prevent understanding by increasing the cognitive load experienced. Texts with a high degree of cohesion tend to be easier for non-expert readers to read than texts in which more connections have to be made by the reader (McNamara & Kintsch 1996; McNamara et al., 1996). Knowledge gaps are less prevalent in coherent text. This is especially important for low-knowledge readers that approach content with limited background knowledge. High-cohesion text reduces their cognitive load, allowing them to more easily obtain a robust understanding without a complete reliance on inferences.

The organization of text contributes to its level of cohesiveness. Structuring it properly ensures clarity and a decreased reliance on conjecture. Hartley (1981) describes information mapping as a mechanism that ensures greater clarity by organizing and spacing text in a coherent manner. Similar ideas are arranged together to create consistency and ensure focus. Their separation into paragraphs allows cognitive effort to be applied in chunks. Using information mapping, new knowledge can be constructed actively and coherently. Through unification, non-expert readers are able to digest and sort information more efficiently.

Text can be designed for cohesiveness in several other ways. Britton and Gulgoz (1991) developed comprehension principles for text based upon Kintsch's model of text comprehension (Kitsch and van Dijk, 1978). A text used to train Air Force recruits was modified so old information preceded new information and implicit inferences were explicit for the reader. Even though readability tests showed no difference between versions, participants of the modified group performed better on free recall tasks and inference-based questions. It is clear that a cohesive text impacts both engagement and comprehension. Additionally, this study shows that readability tests are not always sufficient tools to measuring the readability levels of text. Instead, designing readable text relies on a balance of both qualitative and quantitative components.

Learning by listening. Audio-based storytelling has existed for much of human history. The only way for an individual to receive information by listening was through in-person contact. The progression of technology has allowed audio to be accessed at any time using an internet-connected device. This has changed the frequency of learning by listening, regardless of geography. Listening comprehension involves the same orchestration of cognitive skills as reading comprehension (Pearson & Fielding, 1983). Knowledge is constructed in a concurrent timeline, requiring the activation of prior information and inference to fill gaps in understanding. Although, the audio channel has affordances and challenges that impact the learning process as a whole. This includes higher memory demand due to its live-like nature and audio characteristics that text is without. In order to properly understand how audio impacts learning, we must understand its comprehension process and the design principles that best respect it.

Audio comprehension process. The transmittance of information through speech is a common way for humans to quickly communicate. Although recorded audio can be played back, audio still requires consistent attention due to its live-like nature. Since it is the least explicit of all language skills, meaning can sometimes be lost or confused. Oration is a flexible consumption method, but contains features that can directly impact comprehension.

Novice listeners learn by utilizing a comprehension strategy that is dependent on top-down processing. Young (1997) explains learning by listening as utilizing background knowledge to form a mental representation, identifying gaps in understanding and employing inference according to contextual and acoustic clues to result in finalized meaning. Similar to text, this is an active process that supports constructivism. As new knowledge is constructed, it is stored and continually utilized to form new meaning. Throughout this process, cognitive load limits the content that can be consumed through the auditory channel. Working memory, considered the bottleneck of information processing, directly influences cognitive load (Mayer & Moreno, 2003). If its maximum extrema is reached, comprehension will suffer as a result.

Unlike with static text, verbal information cannot be easily reviewed according to individualistic stages of comprehension. Vandergrift (2004) describes oral text as existing in real time, requiring quick processing where only a mental representation can be relied upon at its conclusion. Berne (2004) stresses the active nature of listening comprehension as one where listeners consistently orient themselves “on-the-go” according to the information being heard. Listeners are required to consciously focus on details at the limitation of working memory. In order to successfully make interpretations through a robust understanding, individuals must be attentive and flexible in their listening activities.

Information is being fed to the reader in a dynamic style that is unique to the creator. The listener must react in real time according to their individualistic learning abilities. The prosodic features of voice provide additional information that influence how information is perceived and meaning is drawn. This is a positive trade off to having real-time material. Pitch provokes action from the listener and stress directs focus to important concepts (Berne, 2004). The ability to direct attention impacts both engagement and the ability to critically evaluate, both influential to comprehension. Individuals are able to more coherently identify relevant information. In turn, meaning can be formed that would otherwise not have been possible.

Learning by listening is subject to additional input that can improve comprehension or cause it to break down. A mental representation is used by the listener to construct new knowledge. The cognitive load experienced by listeners is unique to its medium. Imhof et al. (2014) describe the phonological loop as a combination of verbal and non-verbal information contained within working memory. Individuals are able to collect details about both content and voice characteristics. In conjunction with real time processing, those attentively listening experience significant memory demand. Realistically, its structure affords the opportunity to perform other tasks while listening. This may be an attractive feature for learners, encouraging them to actually access information to some degree. Overall, supplementary information yielded by audio influences the fundamental comprehension process through attentive requirements and elements of discourse.

Designing listenable audio. A listener consistently constructs meaning from audio with unique delivery characteristics that occurs in a real time environment. Audio introduces a range of information that must be processed quickly to assign meaning. The design principles for aural comprehension leverage its strengths for identification and personalization. Proper design involves leveraging the versatility of speech and respecting working memory limitations.

Listeners draw meaning from audio in order to close knowledge gaps. Any information deemed relevant will be utilized to make interpretations that take shape as mental representations (Vandergrift, 2004). More effort required by an individual to discover the message translates into increase cognitive load. Therefore, audio should only contain information that is pertinent. This includes context and focused topics that convey the correct ideas. Littlemore (2001) explains that misunderstanding is less negatively impactful than non-understanding, in which listeners can identify knowledge gaps and implement strategies to remedy comprehension. Designing audio to have a cohesive roadmap improves listenability by minimizing the need to infer.

The structure of audio clearly influences how interpretations are made. More cohesive text prevents a continued reliance on inference, freeing working memory from a hunt for meaning. Working memory constraints continue to limit the comprehension abilities of beginning listeners. Using advance organizers allows listeners to free attentional capacity by helping them identify desired information (Vandergrift, 2004). By ensuring efficient processing, individuals will experience decreased cognitive and increased comprehension. An organized oral message reduces noise that could cause confusion and auditory channel overload. Listenable audio should begin with clearly labeled sections and short summaries so the listener can accurately direct attention and background knowledge.

Well-constructed audio content supports the listener with information and tools that support learning. Comprehension can be enhanced by leveraging the dynamic facets of voice. Richards (1983) details these as “medium factors” that should be designed according to their considerable effect on how messages are understood. These include rate of delivery, rhythm and stress. The speed of speech impacts how effectively information can be processed in real time. Listenable audio has an average speech rate and pauses that properly represent both new sentences and paragraph breaks. Additionally, words should be spoken in a consistent tempo where highly pertinent words can be accentuated. Properly designed audio can direct attention to what matters most.

Listenable audio is designed best when attention is clearly drawn to relevant information. Controlling extraneous load leads to better auditory information processing. Empirical studies suggest noise irregularity, such as distracting sounds or a raspy voice, impact the quality of the mental model formed from discourse (Imhof et al., 2014). The introduction of these irrelevant details increases the listening load, negatively impacting the comprehension abilities of the listener. Properly designed audio contains limited irrelevant background noise and a discernible, smooth voice. Doing so allows meaning to be readily extracted from material to construct new knowledge concurrently.

Medium comparison. Information is presented in a variety of mediums to convey a message. Whatever the form combination may be, content should be specifically tailored for the intended audience to allow efficient processing and the construction of new knowledge. All forms of information share the same fundamental comprehension process, but each influence cognitive load by requiring different skills. Visual text exists statically and can be easily reviewed at will, but requires complete attention when being consumed. Audio is a multifaceted vocal instrument that can accurately coordinate attention and flexibility, but commonly lacks full attention. An individual will choose what medium to consume information from according to established preference stemming from situational needs and learning abilities. An open and mobile learning ecosystem must provide access to text and audio options, ensuring the individual can make a tailored choice.

Differences between modalities. In order for learning to occur, comprehension must first be successful. An individual approaches content with a specific repository of background knowledge. It is utilized to identify gaps in understanding where inference will be used to create a full mental representation. Minimizing the need to guess meaning, therefore decreasing cognitive load, provides an optimal condition for comprehension. Text and audio convey information in different ways, altering cognitive load through efficacy, scale and timeline.

Written and spoken language are different, each processed by different channels that are subject to overload. The unique elements of each can be an affordance or hindrance according to the individual. Reading is commonly performed with full visual attention while listening may contain external activities amidst stimulation of the auditory channel. Flexibility persists as a common theme with spoken language, but requires the listener to organize additional information.

Buck (2001) describes listening comprehension as dependent on phonological modifications and real-time occurrence. The prosodic features of audio can positively impact comprehension by corralling and directing attention effectively. Although, this additional acoustic input can also cause distraction. The rigidity and permanency of text is without this additional layer that could contribute to comprehension breakdown. Information that is the most coherent will be understood the best.

For non-experts, new knowledge is more likely to be constructed when speculation is reduced. Text can be reviewed consistently due to its fixed nature whereas audio requires quick handling before its disappearance. The formation of more links between the incoming information and background knowledge will benefit overall learning (Mannes & Kintsch, 1987). Listeners are left with a mental representation that is refined in a distinctly different way, creating an integration challenge where attention capacity can fill. Readers are able to actively review text with minimal effort in order to fill knowledge gaps. The individual must determine if reading or listening is the best choice for situational learning.

Learner preference. Technological developments have improved quality and increased access to information in text and audio forms. In an open learning ecosystem, learners are able to exercise choice when selecting content. Tamir (1985) conducted a meta-analysis of 54 publications, determining that learner preference among high school and college students is related to "cultural background, grade levels, discipline being studied, curriculum approach, career goals and achievements." Learning preference is shaped by experience. For example, exposure to technical topics throughout school will weight preference towards more complex information. Individuals will select the medium form that historically has allowed them to experience successful comprehension.

Individuals acquire and process information for learning according to their preference (Chang, Hung & Lin, 2015). For example, Sun et al. (2003) explains that some learners may engage better with verbal material and obtain little meaning from written text. Sub-optimal levels of engagement and motivation is evidence of an inefficient learning process (Sadler-Smith, Allinson & Hayes, 2000). Individuals will consume information in forms they know are most conducive for their learning. Since preference is individualistic, creators of content should always intently understand the audience.

The characteristics of text and audio are unique, influencing learner preference. An integral feature of audio is its flexibility (Yeh, 2014). Compared to text, it caters to a higher degree of individual differences. Audio creates a humanistic connection and appropriately clarifies prosodic patterns that are difficult to infer from written text (Berne, 2004). These features can positively impact clarity and engagement, an integral feature of learning. Although, the greater informational input of audio may cause confusion for the listener. Learners will prefer the medium form where they experience the least cognitive load from comprehension.

Since text occupies the visual channel, it requires full attention. This can be beneficial for comprehension depending on the type of information. Some students may prefer to read rather than listen depending on the complexity of the task. Bowles-Terry, Hansley and Hinchliffe (2010) studied the form of online video tutorials for academic libraries. A student suggested they would prefer text instructions for a complex topic so they could repeatedly review the material. Since audio-based material occurs in real time, review is significantly more difficult.

As can be seen, learner preference is impacted by situational context. In practicality, audio is usually listened to while conducting another activity. It's intuitive integration into daily lives is an affordance that many learners may prefer. Assuming they own a mobile device, they can access learning materials on the move (Yeh, 2014). Students can listen to a podcast when the visual channel is occupied, like driving or walking to class (Stiffler, Stoten & Cullen, 2011). Recorded audio is flexible enough that it can be listened to in accordance to the needs of the learner.

Learners can benefit from access to text and audio material. For example, students would be able to further review the content of a lecture outside of the classroom. Huntsberger and Stavitsky (2007) supplemented the text material of an introductory mass media course with podcasts 15 to 28 minutes long. Of the 249 students, 95% indicated that the podcasts contributed to their success in the class. They benefited from having access to both forms of information. Providing access to several mediums will allow the learner to properly exercise their preference.

Multimedia learning. A flexible learning environment should actively decrease working memory and increase learning. It is important to identify the structures that promote optimal learning for a diverse audience. Independently dispersed text or audio may not provide sufficient information for the consumer to draw meaning from. In order to decrease working memory, multimedia material activates the auditory and visual channels, providing input that can be used to form meaning. This avoids the redundancy principle, describing similar input on the same channel as detrimental to cognitive load (Mayer, 2005).

Pastore (2016) surveyed 148 undergraduate students about media types, asking them to describe mental effort required and overall perceptions. Participants answers aligned with multimedia principles, showing that multiple representations were preferred over single representations (Mayer, 2005; 2014). They preferred image and text over image and sound because they would be able to reread if necessary. Text, narration and images was the most popular selection and reflected the least cognitive load. This directly violates the redundancy principle, but qualitative data showed learners most preferred options. Yu, Zhang, Zhou and Li (2005) recommend learners should be able to choose their method of delivery. Therefore, an open learning ecosystem should not be strictly multimedia-based. In order to fulfill preferences, learners should have access to versatile materials that can be utilized in conjunction. Providing a learner with the ability to freely choose allows them tailor their selection towards content with minimum cognitive load.

Technological advancements have increased diversity, quantity and access for learning material. Information can be accessed anytime, anywhere with the use of mobile devices. Employees are able to flexibly fill their commute time with podcasts and students can read online to supplement their in-class learning. Open learning environments provide individuals with options that can be selected according to preference and lifestyle patterns. Researching the consumption methods and comprehension results for reputationally advanced content will provide valuable insight on learning activity. Specifically, this study will examine the role of text and audio in an online course to identify how to elicit engagement and comprehension.

Text continues to be the most popular and simplistic medium for the creation and delivery of information. Although, audio-based methods of content consumption have become increasingly popular due to accessibility and lifestyle integration. The first hypothesis is that individuals with access to only text will experience better comprehension then audio-only. The second hypothesis is that the frequency of access for audio will be higher than text. Lastly, the third hypothesis is those with access to text and audio will experience the highest level of comprehension due to more versatile access to information.

Method

The Internet has democratized access to information. Technological devices allow it to be accessed on-demand. This kind of flexibility is crucial for an open learning ecosystem that is driven by the preferences of individuals. Understanding the role of choice for non-expert learners, it is important to investigate how content is consumed. A robust understanding of learner activity will allow for the enhancement of online courses.

Participants

It was identified that a diverse population would yield the most optimal and impactful results for this study. Undergraduate students from the University of Lagos in Nigeria, Africa and Arizona State University in the United States were recruited as participants. International students were reached through a single point of contact that was a leader at their on-campus blockchain club. Local students were contacted by utilizing the class email lists of professors to spread awareness of the study. Recruitment was performed through email. All participants were required to speak fluent English, be at least 18 years old, own a smartphone device and have access to reliable internet. No other identifiable information, such as gender or exact age, was accumulated. Participants were recruited had varying knowledge and interest levels relating to blockchain technology.

A minimum threshold of 60 participants was established in order to effectively identify effect size. During sign up, participants were asked to complete a consent form and provide recommendations on topics they were most interested in. A total of 60 participants began the study, 50 from Nigeria and 10 from the United States. African participants were members of a campus blockchain club while the involvements of those from the United States was unknown. Significant attrition resulted in only 16 participants completing the study. All communication with participants was performed through email for the duration of the study.

Conditions

To examine learning over a period of time, a longitudinal one-way design with three conditions was utilized in this study. As Table 1 shows, participants were randomly assigned to three different conditions using a random number generator, resulting in 20 students per condition. Each had access to particular forms of material: text only, audio only or both. Every week, three new topics were posted for a total of nine over the course of three weeks. Participants were able to access topics from past weeks throughout the course of the study. Participants were required to access information from a mobile device by logging into a hosted website with provided credentials.

Table 1 Description of conditions	
Condition	Description
Text	Participants assigned to this condition were granted access to information in text form only. They were limited to consuming information by reading.
Audio	Participants assigned to this condition were provided access to identical content, but in the form of pre-recorded audio. They were restricted to consuming content by listening only.
Text/Audio	Participants assigned to this condition were allowed access to both mediums, text and audio. They were allowed to access information in any pattern they believed would be most conducive for learning.

Materials

The Internet is an exceptional resource for effectively accessing a vast amount of diverse information according to learning goals. This has improved the inclusivity of learning by preventing the need for in-person access to teaching. Individuals are able self-learn by consuming information at their own pace and in their desired medium. Therefore, to simulate a typical learning environment, this study was composed of entirely digital materials that would commonly be found within a MOOC. To begin, participants were provided a three-part pretest created with Google Forms. The first part contained onboarding questions to identify the specific topics participants would be most interested in learning. The second part was a consent form to confirm necessary requirements. Finally, the third part was a pre-test on broad blockchain knowledge to obtain a baseline reading of comprehension. At the end of each week, participants were provided a weekly check-in survey to obtain behavioral information. Lastly, to complete the study, a post-test was issued to examine comprehension change in repeated and new questions. Participant activity patterns were observed throughout the study using a website analytics system.

Pre-test. Engagement is a contributing factor to overall comprehension. Individuals, especially those that are non-experts, are able to more easily engage with material they find approachable and relatable. A Google Form pre-test, found in Appendix A, was used to enroll participants. The first part contained onboarding questions to elicit information on interested topics specific to cryptocurrencies and blockchain technology. The information provided was used to create the learning materials for the study. The second part of the pre-test contained a consent form that confirmed personal characteristic requirements. Participants were required to complete it before enrolling in the study.

The third part of the Google Form pre-test was a series of five higher level questions focused on the blockchain space. Only a general understanding was required to successfully answer the questions. A quantitative scoring system, found in Appendix B, was utilized to calculate a baseline comprehension score. Answers to questions were determined by identifying what fundamental concepts were essential to exhibit understanding. Participants earned a point for each correct answer.

Weekly check-in. An open learning ecosystem introduces the concept of choice. Decisions can be made according to an individual's learning goals. Therefore, it is essential to examine the intersection of learner preference, lifestyle and consumption. Doing so will provide valuable insight on how learners commonly perform when at their own pace. At the end of each week, a check-in survey was sent to participants. Found in Appendix C, questions were created to determine what activities, if any, participants were doing while consuming material. Additionally, students were asked to estimate the time they spent learning in current and past weeks. Analyzing overall behavior allowed for the identification of potential patterns that could support optimal learning paths.

Post-test. Upon completion of the study, participants were sent a post-test that can be found in Appendix D. The first section of the post-test contained identical questions to the pre-test. The same comprehension scoring sheet from Appendix B was utilized to determine comprehension levels. The comprehension scores for repeated questions were compared to identify if gain occurred. The second section of the post-test contained new questions that required an understanding of learning topics present in the course. These questions were scored with a quantitative scoring sheet found in Appendix E. A higher comprehension score represented successful learning during the study.

Learning content. Text and audio are two extremely prevalent mediums in which information exists. Learners exercise their preferences to select content they are confident will help them construct new knowledge. In this study, participants were assigned to conditions with particular access to text and/or audio materials. Due to the non-expert participant pool, design followed the recommended principles discussed prior. Additionally, to facilitate the highest amount of engagement, learning material topics were created directly from participant. The most prevalent recommendations were selected. All material was related to blockchain technology and cryptocurrencies. A total of nine topics were presented to participants at a rate of three per week. A summary of each can be found in Table 2 with full copies present in Appendix F.

Table 2

Description of learning content

Week 1: Fundamental Concepts		
Overview of Money	The barter system transformed into a standardized system using money backed by belief becoming the de-facto exchange tool.	1,127 words
Blockchain Basics	Blockchain is an innovative technology where distributed nodes maintain a network by recording immutable information.	734 words
Introduction to Mining	Mining is the use of powerful computers to solve advanced math problems in order to verify transactions for the blockchain.	949 words
Week 2: Digital Assets		
Bitcoin Basics	Bitcoin, the first successful cryptocurrency, utilizes a blockchain to transmit value without any oversight of a centralized entity.	1,122 words
Entry to Ethereum	Ethereum is a more versatile blockchain that acts as a distributed computer, allowing anyone to build a decentralized application.	1,165 words
Stablecoins 101	Typical cryptocurrencies are volatile due to speculation, but stablecoins are pegged to protected fiat money to maintain value.	828 words
Week 3: Getting Specific		
Smart Contracts 101	Smart contracts are agreements that execute when requirements are met, preventing the need for a trusted intermediary.	636 words
The Lightning Network	The Lightning Network solves the scalability problems of Bitcoin by utilizing pre-funded payment channels between nodes.	615 words
Blockchain Disruption	Blockchains are a trustless way for networks to operate, increasing security and privacy for many industries that are vulnerable.	544 words

Text. Information was originally drafted in text form. Google Docs was utilized to create and edit drafts before deploying a live version on the testing website. The main focus during creation was to minimize the amount of inference necessary to construct new knowledge. Text with a high amount of cohesion are easier for non-expert readers to engage with and comprehend (McNamara and Kintsch 1996; McNamara et al. 1996). Therefore, text design principles focused on improving readability with cohesiveness were implemented. This includes analogical ties, chronological ordering and information mapping. Analogical ties allow readers to more effectively activate background knowledge (Pearson 1983). Several modern-day comparisons were incorporated to reduce understanding gaps for participants. To further improve coherence, text material was structured like a narrative with old information preceding new. This type of structure was recommended by Kitsch's model of text comprehension (Kitsch and van Dijk 1978). Lastly, information was mapped in topic-focused sections utilizing headers. By improving organization and spacing, a message can be conveyed more clearly (Hartley 1981). Therefore, information chunking was an integral tactic to structuring text so that it would be the most coherent.

Audio. The Yeti Pro, a podcasting microphone, and Audacity, an audio recording program, were used to record all audio material. There were no changes to the actual wording, only the incorporation of voice characteristics. It was then hosted using Soundcloud. Just like written text, audio should be designed in a cohesive manner to ensure comprehension. Advanced organizers were used to allow listeners to more easily activate background knowledge (Vandergrift 2004). Information was presented in chronological form, preparing the reader with an overview before more details. The major difference between text and audio was the use of voice characteristics to ensure engagement and connection. Audio was recorded with delivery, rhythm and stress in mind (Richards 1983). A conversational pace was used in order to mimic a familiar scenario for the listener. Additionally, important phrases and definitions were stressed using a tougher intonation to help the listener identify its level of importance. Although identical to the written text in content, audio materials incorporated voice characteristics that were implemented to improve comprehension.

User interface. All content was accessed through a responsive website, as seen in Appendix G. All website code was deployed, using Netlify, to a domain purchased from Namecheap. This domain was meetsatoshi.com. The website was hosted using Amazon Website Services. The visual display of the website was designed using Webflow, a no-code visual developer tool. This code was then exported for deployment. Using Laravel, a PHP programming language, a login system and backend administrator panel were created. This allowed for the creation and assignment of new participant accounts. Participants were provided login credentials that would direct them to materials representative of their assigned condition. Text was displayed in a blog format without any accompanying imagery. Additionally, Soundcloud audio files were embedded where necessary using code provided from their platform. New content was posted in weekly increments, separated by colored banners. Overall, the website incorporated a very simple login feature that directed participants to their assigned material that could easily be consumed on a smartphone device.

Analytics platform. An important metric of this study was examining the website activity of participants. A snippet of Google Analytics code was placed in the code of the website to track individual participants. When they first visited the website, a cookie was embedded in their browser. This allowed activity to be anonymously tracked using a client ID. No tracking was performed outside of the website and no personal information was obtained. Using Google Analytics, all movement on the website was recorded including access of text material and play/pause of the audio file. All information was displayed on the general Google Analytics dashboard. Since participants were routed directly to their assigned condition, analytics data was grouped accordingly.

Procedure

Before beginning the study, students completed a pre-test survey to gauge topic interests, confirm participant requirements and determine their baseline comprehension. Those that successfully completed it were enrolled as a participant in the study. They were randomly assigned to conditions and sent their login information through email. The material for week one was made live for them to access on the website. This information was strategically created to provide learners with an introduction to core concepts. Participants were instructed they could learn at their own pace, but must visit the website strictly from their smartphone device. At the end of week one, students completed a check-in survey that asked them about their consumption tendencies. Next, participants were issued week two's content while retaining access to material from week one. This week's information focused on specific examples of cryptocurrencies. To conclude week two, the second check-in survey was emailed to participants. Finally, students were provided access to week three's material. In it, more advanced concepts were discussed to challenge the learner to apply their newly accrued knowledge. Upon conclusion of the study, participants were issued a post-test to identify their final comprehension after experiencing the learning environment. Of those that successfully completed the study, two individuals were randomly selected for rewards.

Analysis

There were several areas in which data was analyzed. The first was comprehension tests at the beginning and end of the study. Throughout the study, check-in surveys were structured to create valuable information about the intersection of lifestyle and learning. Finally, Google Analytics provided valuable information on the activity of learners. Utilizing this information, conclusions were reached on how open learning ecosystems function.

Pre and post-test. Participants completed an introductory test to determine a baseline comprehension level. Answers were scored using the quantitative scoring checklist found in Appendix B. Depending on complexity, some questions contained several answers. For each correct answer, participants earned one point. It was possible to earn partial credit on questions with multiple answers. The final score was tallied for each participant. A one-way ANOVA was run across conditions to confirm there was pre-test equivalence. For accurate results, comprehension levels should be near the same level across conditions.

After learning for three weeks, participants were issued a post-test to determine their final comprehension level. The first section contained the five repeated questions present on both tests. Answers were scored using the same checklist and process, tallying their final score. A 2x3 repeated measures mixed ANOVA was performed to closely examine the interaction between condition and gains.

The material of the course introduced new information that may not have been known prior. Therefore, five new questions were added to the second section of the post-test. Since these questions were not present on the pre-test, a 1x3 ANCOVA was performed to investigate comprehension variance across conditions. Hedge's g was calculated for all comprehension results to determine effect size between conditions.

Check-in surveys. Check-in surveys provided both qualitative and quantitative data about lifestyle patterns and learner behavior. Participants described activities, if any, they performed while accessing content. Commonly occurring activities were recorded to compare with consumption method. Additionally, data on time spent learning was obtained. Condition averages were calculated each week and a chi-square test was performed to compare condition and time-spent categories. This identified if time spent was condition-specific.

Website tracking. The website activity of each participant was tracked and analyzed by condition. The goal was to determine trends that might be present in each condition and how they might be related to comprehension. The metrics recorded involved frequency of access represented as once or more than once each week. A one-way ANOVA was conducted for each week to determine if there was any significant variance between conditions. This provided insight on the behavior participants exhibited according to condition.

Results

The goal of this study was to determine how certain material forms impacted the learning process. To do so, data relating to comprehension, activity and learning patterns was compiled. Unfortunately, significant participant attrition was experienced. This is extremely common among MOOCs and can be attributed to the openness and multi-stage structure of this study. Participant involvement diminished with little guidance alongside a new learning responsibility. Results were still investigated for potential trends.

Learning

Learning is a multidimensional process that is influenced by mediums. Data compiled in this study sought to identify if comprehension was affected by form and how consumption methods played a role. Statistically significant differences were not able to be accurately identified due to the attrition experienced. This could have been due to a variety of influencing factors that will be covered in the discussion. Although, several patterns were identified that provided limited insight on condition impact.

Pre-test equivalence. It is essential for the randomly assigned conditions to begin with similar comprehension levels. Imbalanced starting levels prevent the ability to properly recognize change over time. Utilizing the scoring sheet in Appendix B, initial comprehension levels of conditions were calculated and placed in Table 3. In order to confirm their equivalence, a one-way ANOVA was performed with a 95% confidence interval. Since p was greater than 0.05, it was confirmed that baseline comprehension levels were not significantly different across conditions. Condition assignments were sound in structure, creating a valid foundation for testing to begin.

Table 3 Pre-test equivalence one-way ANOVA data					
Condition	N	∑X	Mean	$\sum X^2$	Std. Dev.
Text	20	163	8.2	1361	1.3
Audio	20	166	8.3	1410	1.3
Text/Audio	20	168	8.4	1438	1.2
Total	60	497	8.3	4209	1.3

Table 4 Pre-test equivalence one-way ANOVA results				
Designation	SS	df	MS	F = 0.19 p = 0.82
Between treatments	0.63	2	0.32	
Within treatments	91.55	57	1.61	
Total	92.18	59		

Repeated and new questions. Throughout the study, participants were provided nine pieces of content with topics that became incrementally more difficult. It was structured so knowledge gained from past lessons would be used to understand future ones. Again, only 16 participants successfully completed the study. The data located in Tables 5 and 6 represents 25.4% of the total population. This was a higher participation rate than most MOOC's which commonly conclude with only 7% of original participants (Rai & Chunrao, 2016). A limited sample size prevented valid statistical tests from being run. Instead, a general pattern can be inferred from the metrics seen in Table 6. Conditions with access to text scored an average of 10% better than the condition with access to strictly audio. The full attention text required and the ability to easily review may have contributed to higher comprehension scores. Those with access to text alone scored slightly better than those with access to both mediums, potentially showing that greater options do not always equate to increased comprehension. Instead, a narrowed and structured focus may be the most beneficial for the learning process.

Table 5

Comprehension metrics for tests

Condition	Repeat pre-test		Repeat post-test		New post-test	
	M	SD	M	SD	M	SD
Text (n=7)	7.6	1.1	10.9	0.6	9.4	0.9
Audio (n=4)	8.3	1.1	9.3	0.8	8.0	0.7
Text/Audio (n=5)	9.4	1.0	10.4	0.5	9.0	0.9

Although statistical significance could not be tested, Hedge's g was calculated to determine effect size between conditions. This metric was chosen because sample sizes were all below 20 and non-identical. Seen in Table 6, comprehension means differed severely between text-related and audio-only conditions. On average, the effect sizes between the text only and audio only conditions differed by two standard deviations. The smallest difference in comprehension data was between the conditions incorporating text.

It is clear that the permanence of text positively influenced comprehension while the live nature of audio materials resulted in poor comprehension and large effect sizes.

Table 6

Hedge's g for mean comprehension differences between conditions

Comparison	Repeat post-test	New post-test
Text vs. Audio	2.4	1.7
Text vs. Text/Audio	0.9	0.4
Audio vs. Text/Audio	1.7	1.2

Behavior

Beyond comprehension metrics, it was essential to obtain details about the learning process. This allowed for observation of the intersection between consumption patterns and learning. Unfortunately, this study experienced significant attrition over the course of three weeks. With little structure, an extended timeline and a digital-only testing environment, only 25.4% of the recruited population completed the study. Participants that remained belonged exclusively to the Nigeria population. A lack of subjects prevented all statistical tests from being conducted due to an absence of validity. Instead, several trends were observed that could provide insight on the learner process.

Attrition. This study occurred over the course of three weeks in a completely digital environment. There were no in-person meetings with participants. Additionally, a very open course schedule required students to motivate themselves and structure their own learning process. Self-driven accountability is difficult without some sort of guiding mechanism. Rewards were offered through a raffle system, but no guarantee of a reward may have led to lower motivation levels amongst participants. All of these features of the study process contributed to significant attrition.

The text condition retained slightly more individuals overall. Seen in Table 7, all conditions lost participants in a similar week-to-week pattern. Due to the small size of American participants, the 16 individuals that successfully completed the study belonged to the Nigeria pool. Both demographics experienced similar levels of attrition, but the 10 individuals from Arizona stopped participating completely two days after the study began. In contrast, Nigerian individuals began to churn upon completion of the first week. These results support the idea that topic interest strongly influences engagement and attention throughout any course with complex content.

Table 5

Participant frequency

Condition	Pre-test	Week 1	Week 2	Week 3	Post-test
Text	20	13	9	7	7
Audio	20	9	7	4	4
Text/Audio	20	11	7	5	5
Total	60	36	23	16	16

Website Activity. Activity was examined for those that successfully completed the study. Heavy attrition prevented a large enough sample size to run a statistically accurate one-way ANOVA to determine significance between groups. All conditions experience similar attrition rates. All final participants accessed content once throughout the study. More than half of the text only condition commonly accessed material more than once. As concept difficulty rose throughout the study, participants of conditions one and three spent 30 to 60 minutes learning and reviewing content. Participants of the audio only condition spent half the time consuming and reviewing content.

It is clear that text was the preferred consumption method. These results also support the concept that text is significantly easier to review. The time spent solidifying concepts could have contributed to higher comprehension scores. Nearly all participants in the third condition of text and audio accessed text exclusively. Even when provided the option, audio material was not leveraged in the learning process. The condition restricted to audio represented the only audio usage of the study. Of the limited sample size, the web activity of participants clearly showed text as the desirable consumption method.

Table 6

Website activity for week one

Condition	Accessed content only once	Accessed content twice or more	Mode for minutes spent on current week
Text (n=7)	7	5	<30
Audio (n=4)	4	1	<30
Text/Audio (n=5)	5	2	30-60

Table 7 Website activity for week two				
Condition	Accessed content only once	Accessed content twice or more	Mode for minutes spent on current week	Mode for minutes spent on last week
Text (n=7)	7	4	30-60	30-60
Audio (n=4)	4	0	<30	<30
Text/Audio (n=5)	5	1	30-60	30-60

Table 8 Website activity for week three				
Condition	Accessed content only once	Accessed content twice or more	Mode for minutes spent on current week	Mode for minutes spent on last week
Text (n=7)	7	4	30-60	30-60
Audio (n=4)	4	0	30-60	None
Text/Audio (n=5)	5	1	30-60	30-60

Alternative activities. Individuals consume content in unique ways according to preference. Depending on attention requirements and lifestyle patterns, learners can listen or read while simultaneously conducting another activity. It is crucial to understand how content is accessed in order to deliver it in forms that are the most conducive for learning. Each week, participants were polled about attention habits while consuming material. Table 11 represents the breakdown of activities performed while learning. On average, 70% of individuals expressed they strictly focused on the content when learning each week. Regardless of condition assignment, most survey respondents described a focused learning process. The remaining 30% of participants explained they performed other activities while learning. The audio only condition had a significantly higher rate of divided learning as compared to any condition with text. Since most daily activities require visual attention, these results were not unexpected. Listening to audio leaves the visual channel open to perform visual-based activities.

Table 9

Alternate activities while learning

Condition	Focused	Divided
Text (n=7)	38.4%	5.4%
Audio (n=4)	5.9%	19.1%
Text/Audio (n=5)	25.1%	5.9%
Total	70%	30%

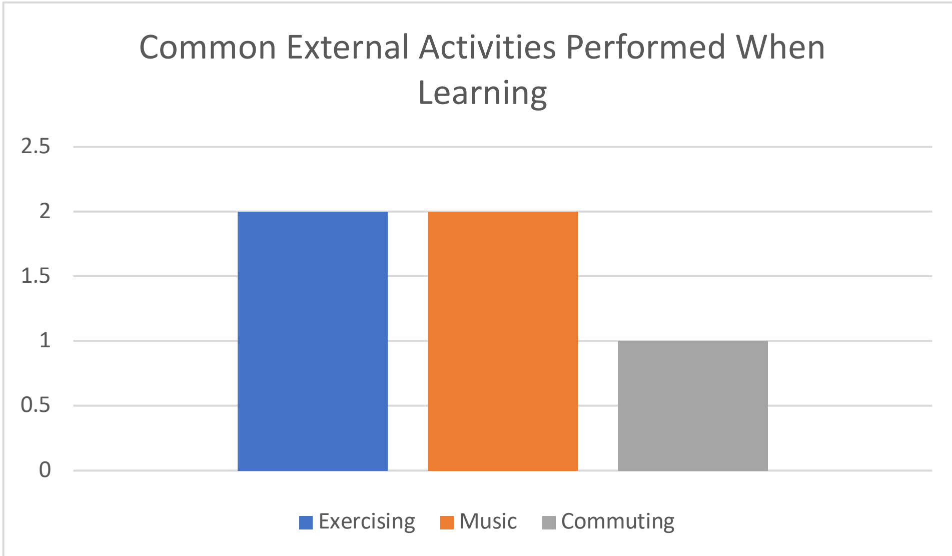

Figure 1: Recurring external activities

A majority of students in this study learned in a focused manner without performing any other activities. These results could be partially attributed to the survey completion rate of participants with access to text material. Most external life activities cannot be performed without the visual channel free. Figure 1 shows the most common external activities performed by participants that completed the study. The only external activity performed by those with access to text was listening to music. This cannot be described as a trend since it represents a very minimal subset of the population. All participants in the audio only condition performed external activities while learning. Roughly two-thirds of all divided learners were members of this condition. Since much of life involves visual stimulus, participants with access to audio found it most convenient to consume material while conducting another action. This may have also contributed to their lower comprehension scores. Overall, content was most frequently consumed in a focused setting, but those in the audio only condition were divided learners.

Discussion

The growth of the Internet and connected devices transformed the way information is accessed and consumed. The flexibility of online learning ecosystems empowers individuals to construct new knowledge in an efficient and timely manner. They are able to shape their learning process according to style and preference. Learners are able to participate in Massive Open Online Courses (MOOCs) to fulfill their learning goals. Understanding how choice plays a role in the modern, online learning process is essential to creating sound educational materials and instruments.

Recognizing the expansiveness of choice that permeates online learning, this study investigated how text and audio influenced comprehension and engagement. Participants were randomly assigned to three conditions with access to different digital compositions: text only, audio only or both. Unique comprehension change was identified using a pre-test and post-test. Additionally, behavior patterns and tendencies were recognized using weekly check-in surveys and an online analytics tracking system. With this, insight was gained on how content form impacted the overall learning process.

Major Findings

The flexibility of open, online learning can have a positive and negative influence on an extended testing process. Even with engrained interest, participation is challenging due to digital logistics. Over the course of three weeks, all conditions experienced significant attrition resulting in 16 participants who fully completed the study. All of these individuals belonged to the Nigeria pool, the largest population subset with confirmed interest in the topics presented within the study. Due to a limited sample size, expected statistical tests could not be run. Although, several trends were identified that provided loose answers to the research questions proposed.

Without the backing of a statistical test, these results should be weighted properly. Comprehension results for both repeated and new questions showed text as the medium most impactful for learning and audio as the worst, supporting the first proposed hypothesis. Furthermore, text was accessed much more frequently than audio, invalidating the second research question. Participants accessed text the most frequently, both initially and more than once. Additionally, the condition with access to both mediums exclusively accessed text and disregarded audio as a learning option completely. These consumption patterns do not support the second hypothesis that audio would be preferred above text. Lastly, those with access to text and audio experienced the second highest level of comprehension. This condition did not leverage audio at all in the learning process like first expected. In entirety, results did not support the final hypothesis.

Readers construct meaning by making connections between text and prior knowledge (Dixon-Krauss 1996). The ability to review material consistently prevents the need to infer and increases comprehension. Audio exists in real-time and requires quick processing to form a temporary mental representation (Vandergrift, 2004). The ability to easily review text supports the activity and comprehension results that clearly showed it as the preferred consumption method. Due to the length and complexity of this study, the transient information effect further supports these results (Leahy & Sweller, 2011).

If inferences are explicit, the reader is able to fill gaps in understanding using little of their own knowledge for the topic (Benjamin, 2011). Since audio incorporates voice characteristics, meaning may not have been conveyed in an explicit way. As a result, it was not an attractive or effective choice for learning. Additionally, decreased cognitive load positively influences comprehension for novice learners (Benjamin, 2011). Less mental stress usually equates to higher comprehension. Roughly 70% of participants respected cognitive load capacity by engaging in a focused learning process. Students in the audio only condition populated two-thirds of the 30% that performed other activities while learning. It can be inferred that participants of the audio condition respected their operational tendencies to fulfill their visual channel while learning. As a result, their comprehension and engagement suffered as a result of increased cognitive load. Supported by the transient information effect, the main takeaway of this study is participants of the text only condition learned the best because they were able to most effectively refine their mental representation.

Limitations

In order to have a broad and diverse subject pool, participants were recruited from two different countries. Therefore, all communication throughout the study was performed digitally, specifically through email. This included all surveys that would provide data on comprehension and learner activity. Pertinent messages sent throughout the study had to potentially fight for attention in the participant’s inbox. Additionally, poorly designed digital communication can lack elements of trust and personality that in-person interaction could provide.

This implication most likely negatively influenced the engagement levels of participants. Those that did not quickly complete surveys were reminded several times. Receiving a significant amount of noise may have discouraged learners from participating further. To counteract this, emails should be sent at early morning times to prevent other information from being piled above it. Additionally, eye-catching graphics should be utilized to effectively engage with all participants.

Distributed learning provides flexibility that is challenging to implement in typical classroom environments. Organizers are able to efficiently create and disperse content that reaches a much broader audience through the Internet. Although, ensuring consistent engagement is a significant challenge for learning systems which most commonly exist as Massive Open Online Courses (MOOCs). This study was structured similarly to a MOOC, so the attrition problems experienced are very much aligned. Popular online courses of recent years show that learners usually lose interest after only a few weeks, resulting in a final participation rate of only 7% (Rai & Chunrao, 2016). Attrition is fueled by passive learning, detachment from a lead teacher, content difficulty and an undisciplined environment.

These are all facets of the educational study that was run. Participants were provided little structure aside from email reminders and weekly content launches. This may have created a passive and undisciplined learning environment that directly impacted learner motivation. Participants had little directional leadership to guide them in the learning process. Lastly, content was focused on reputationally difficult technical concepts. It is clear that topic interest had some influence on participation rate for this study. Future MOOC studies should counteract detached learning by incorporating a lead teacher that has more personal contact with the learning journeys of participants. This improvement could minimize the size of attrition and allow for statistical tests to be run.

Implications

Ecosystems that facilitate distributed learning will continue to grow and enhance as technology drives daily actions. This study uncovered trends associated with learning complex topics through online courses. Similar to other MOOC's, attrition was a major challenge. Participants will remain more active if their personal learning goals are being fulfilled. Therefore, educational material should be specifically catered to the intended audience in order to improve engagement.

Results showed text to be the most popular and effective medium. Leahy and Sweller (2011) conducted an experiment where primary school students were provided long-form material. Participants with strictly visual information performed better than visual/audio. It was determined that both the length and complexity of the content made permanent written information more easily processable within working memory. Known as the transient information effect, this supports the comprehension results and access behavior for participants in the text condition. MOOC's that contain lengthy, complex information should leverage text to a high degree for improved comprehension.

Moving forward, developers of learning systems should ensure text is well-integrated and all material is engaging. Participants with a confirmed interest in the crypto-focused material participated at a higher frequency than those without. It is clear that impact to personal learning goals directly influenced participation. Those that felt the study content was personally beneficial participated for a longer period of time. In order to obtain accurate findings, material should reflect both the interest and knowledge of the audience. As seen in this study, non-expert learners benefit from analogical comparison and short primers. In contrast, expert learners should be challenged to apply background knowledge in ways that increase understanding.

Even though a statistically-backed conclusion was not obtained, the problem framework commonly experienced by MOOCs was confirmed and the value of text was highlighted. There is significant research still to be done on crafting engaging courses that counteract attrition to retain initial members. Future studies should focus specifically on course structure to create a more engaging and disciplined learning environment. Potential features would be video-based accountability checks or short quizzes focused on spaced repetition. Overall, individuals continue to leverage the Internet to fulfill their personal learning goals. Further researching effective learning environments will provide a future-proofed mold for classrooms of the future.

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APPENDIX A

THREE-PART ONBOARDING SURVEY

Part 1

Email Address

____

Full Name

____

1. Do you speak fluent English?

a. YES

b. NO

2. Do you own a smartphone and have reliable access to the internet?

a. Yes

b. NO

3. What kind of crypto/blockchain topics would you like to learn about? Please explain.

Part 2

My name is Quintin Woods, and I am a graduate student working with Dr. Rod D. Roscoe in the Human Systems Engineering program at Arizona State University. I am conducting an online research study as part of my graduate thesis to explore the effectiveness of educational content relating to cryptocurrency and blockchain technology.

I invite you to participate in this study over a period of three weeks from February 18th-March 11th. Each week, you will be offered three new lessons to learn about—a total of nine lessons across the entire study. Content from prior weeks will remain available, so you can always access and review the lessons if you want. You will be provided log-in credentials to access the website where content will be hosted. Altogether, the study will involve about 2-3 hours of time spread across three weeks. Here are the general topics you can expect:

Week 1: Foundational Concepts

Week 2: Digital Assets

Week 3: Getting Specific about Digital Currencies

There will be a short quiz at the beginning and end of the study, and you will be sent a quick survey at the end of each week. You have the right not to answer any questions and to stop participation at any time. By participating, you will be provided with educational content relating to cryptocurrencies and blockchain technology at no cost. Your survey responses will only be used for research purposes to determine the most effective ways to create educational materials.

Your participation is voluntary. All participants who complete the study and answer the final quiz will be entered into a raffle to receive $50.00 worth of Bitcoin. One winner will be selected from all participants (roughly 5% chance of winning), to be notified in April or May of 2019.

Your use of the lessons on the study website (e.g. viewing time and site clicks on the website) will be tracked using Google Analytics. You will be provided with log-in credentials for the website if you agree to participate in the study and complete the first quiz. By logging in, your study website activity and survey answers will be unique to you. Your website-specific activity will be observed using a ‘cookie’ (temporary information file) in your device browser that simply allows us to keep your records organized over time. No other web activity, browser data, device data, or files will be tracked outside of the study website, and your IP address will not be recorded.

Importantly, as a requirement for this study and data collection, you must consistently access content from the same mobile device using the same browser. You will not be accessing this content from a computer. Thus, when you receive the lessons, choose your preferred mobile device and browser, and then continue to use only that device and browser. Doing so will keep the same ‘cookie’ assigned to you and allow us to maintain accurate records for the research study. Please do not clear your browser cookies at any time throughout this study.

Results may be used in reports, presentations or publications in both individual and aggregate form. Before analyses begin, all personally identifying information will be deleted from our records. Ultimately, there are no foreseeable risks or discomforts to your participation.

If you have any questions regarding this research study, please contact Mr. Quintin Woods at qwoods1@asu.edu or Dr. Rod Roscoe at rod.roscoe@asu.edu. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional

Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

If you wish to participate in this study, please type “I agree” in the space below and provide your contact information. Next, you will complete a short quiz.

Thank you for your participation!

Please type "I agree" below if you consent to being part of this study.

Part 3

1. What is money and what is it used for?

2. What is blockchain?

3. What is cryptocurrency?

4. What are a few examples of cryptocurrencies being used today?

5. What makes cryptocurrencies valuable? What does that value come from?

APPENDIX B

REPEATED QUESTION SCORING MATRIX

Answer	Score
What is money and what is it used for?	
It is a medium of exchange because it is used to purchase and sell between individuals.	
It is a store of value whose value is supported by a belief in a system (government, infrastructure, etc).	
It is a unit of account because it is used to measure the worth of goods or services. This allows for equivalent and competitive exchanges to occur.	
What is a blockchain?	
A blockchain does not need a centralized entity to process and store information.	
It is decentralized because a network of nodes maintains the information.	
It is more secure and transparent than common systems because there is no single point of failure and all information is immutable (can't be changed).	
What is cryptocurrency?	
A digital currency whose system operates independently of a government or bank.	
Each are decentralized and built using a blockchain.	
What are a few examples of cryptocurrencies being used today?	
Bitcoin	
Ethereum	
What makes cryptocurrencies valuable? Where does that value come from?	
Similar to traditional currencies, their value is based on belief in a ruling system.	
Cryptocurrencies aren't reliant on powerful central entities, making them desirable and therefore valuable.	
Final Score	/12

APPENDIX C

WEEKLY CHECK-IN SURVEY

Email

____

Full Name

____

1. When accessing the lessons, did you sometimes engage in other activities at the same time, such as exercising, eating, commuting, or something else?

a. No, I focused on the lessons.

b. Yes, I sometimes engaged in other activities.

2. If you answered "yes" above, please tell us about those activities.

3. About how much time did you spend accessing and reviewing all of the lessons this week?

a. Less than 30 minutes

b. Between 30 to 60 minutes

c. Between 60 to 90 minutes

d. Between 90 to 120 minutes

e. More than 120 minutes

4. About how much time did you spend accessing and reviewing lessons from LAST week?

a. None

b. Less than 30 minutes

c. Between 30 to 60 minutes

d. Between 60 to 90 minutes

e. Between 90 to 120 minutes

f. More than 120 minutes

APPENDIX D

POST-TEST QUESTIONNAIRE

1. What is money and what is it used for?

2. What is blockchain?

3. What is cryptocurrency?

4. What are a few examples of cryptocurrencies being used today?

5. What makes cryptocurrencies valuable? What does that value come from?

6. How does mining work? Please explain.

7. How are stablecoins different than fiat currency?

8. How does the Lightning Network help Bitcoin?

9. How so smart contracts work?

10. In what ways is decentralized better than centralized?

APPENDIX E

NEW QUESTIONS SCORING MATRIX

Answer	Score
How does mining work?	
Blockchain transactions are grouped into blocks and encrypted before being added to the blockchain	
Miners rapidly guess solutions in order to solve the math problem of the block	
Upon completion, the winning miner receives a reward for their contribution and the block is permanently added to the blockchain	
How are stablecoins different than fiat currency?	
There are no time restrictions for transferring stablecoins	
A stablecoin backed by a basket of cryptocurrencies is not subject to oversight	
How does the Lightning Network help Bitcoin?	
Bitcoin suffers scalability issues that the Lightning Network helps solve	
It creates a diverse network of pre-funded channels that individuals use to send funds immediately and cheaply	
How do smart contracts work?	
A smart contract exists on the blockchain and is an agreement that self-executes when certain conditions are met	
Smart contracts prevent the need for a third party because its code is not subject to fault or persuasion	
In what ways is decentralized better than centralized?	
Decentralization increases access for individuals that would not normally have access to financial services	
Information is stored in a distributed manner, which increases both security and privacy. There is no single point of failure.	
A centralized entity is not able to change structure without the unified consensus	
Final Score	/12

APPENDIX F

ALL STUDY CONTENT

Overview of Money

It's easy to think of money as just coins and banknotes. In the modern day, this is how we transact. Although, money has changed shape according to needs and resources. Money is anything with value that can be used in the exchange of goods or services. The art of exchange first began with the barter system. Hunters and gatherers identified a personal need and sought out a trade that would provide mutual benefit to another individual. For example, a caveman would offer excess animal fur for animal meat. It was clear that, in their situations, one needed fur while the other needed food. This system of exchange was driven by the desire to survive, a theme that has persisted throughout the history of money. Although, the methods and means to survive have drastically changed. Let's examine the rocky trail of money and how it's changed over time.

Changing Shape

10,000 years ago, the ice age ended and humans began to spread across the globe. The domestication of wheat, grains and animals led to the emergence of farming, causing population density to increase and centralize. The early formation of these dense communities resulted in a change of operations. Instead of a universal skill set composed of hunting and gathering, individuals began to refine specialized skills. The good or service of someone highly experienced in a craft could be exchanged for something they were lacking. Specialization provided a focus for the barter system, but there still remained a major reliability problem. Mutual demand for every good or service would not remain the same day-to-day. Therefore, the unreliability of demand introduced a form of volatility that continued to impact the efficiency of exchange.

The desire for a standardized and controlled transaction system persisted. As time progressed and evolution occurred, money (and the storage of it) continued to take different shapes. Cowry shells were used in trades around Africa and Asia. Early civilizations, like Mesopotamia, introduced a banking system to store valuables like cloth that could be used for trading. As can be seen, various civilizations around the globe each were testing more efficient means of exchange. As commerce grew, certain necessary elements of money were identified. It was required to be physical, resilient and agreed upon. To ensure widespread acceptance, the production and issuance of standardized coins by a central entity (banks) was introduced.

Centralization

Centralized entities issued physical coins in order to improve the reputation and trustworthiness of money. Commonly made of scarce metals, centrally-issued coins ensured there was a controlled supply whose value was vouched for by the government. The rulers of Greece created unique, stamped coins, ensuring their citizens they would maintain their value as long as the civilization existed. Management of money by an official and credible entity influenced widespread acceptance of these currencies. This fulfilled the last requirement of a reliable form of money. Coins fit the mold for sound money, but there were several disadvantages. Molded from precious metals, circulation and availability were limited by the scarce supply of that resource. Although it prevented devaluing through mass production, this limited availability to all citizens. Additionally, metal coins continued to be difficult to store and transport. Mobility was an important component to facilitating exchange, so their physical structure posed a problem to commerce.

First created by the Chinese in 100 B.C., paper became a promising replacement for coins. People were able to leave valuable physical items in the bank and receive a signed note of verification for the existence and worth of the item. These could be exchanged amongst individuals without using the actual physical assets. Eventually, Marco Polo brought the concept of paper currency back to Europe and its value was backed by gold held by goldsmiths. Due to the essentially unlimited supply of paper notes, European banks began to issue more notes than the amount of gold on hand. They believed not all citizens would try withdrawing gold at once, ensuring they'd be able to fulfill citizen requests. Although yet to be seen, this was a step towards money supply expansion that would have detrimental effects.

Gold-Backed No More

For most of American history, every dollar printed in the United States was backed by $0.40 worth of gold. This was known as the "Gold Standard." Similar to Europe, the purpose of it was to ensure value was evident so that it could translate into credibility and reliability. Additionally, the system was based upon the fact that citizens would not redeem their money for gold in such an amount that required it to all be on hand. This system posed a problem when the Great Depression struck. Unable to immediately print more money to support the United States economy, President Franklin D. Roosevelt made private ownership of gold illegal. Gold was reclaimed from private citizens by threatening legal consequences of up to 10 years in prison. In return, they were given paper money. This effort did not stop the Great Depression, lasting another 6 years. President Richard Nixon removed the Gold Standard in 1971 and in 1977, the private ownership of gold was made legal again. The tradeoff of a substantial money supply was the opportunity for overprinting and devaluing.

Recent Developments

As it stands today, the value of paper currency is solely a promise from the government. There is no limited resource that ensures its value. Complete trust is given to the government to properly create and disperse the currency so as to retain its value over time. This trust was soon to be broken. In 2008, the United States was experiencing a recession due to widespread defaults on disproportionately unfair mortgage loans made to unqualified individuals. When they defaulted, banks struggled to stay afloat others tried to withdraw money. To prevent the economy from collapsing causing negative global effects, the United States government issued $145 billion in stimulus packages to bail out banks. The predatory actions of banks not only caused the 2008 Recession, but also contributed to additional devaluing of the United States Dollar through money supply expansion.

In the midst of the economic downturn in 2008, a paper was published to a cryptographer email list detailing a new, digital currency. In it, an unknown person or group named Satoshi Nakamoto described Bitcoin as a decentralized, trustless and peer-to-peer system that did not require a central entity (like a bank) to control and monitor operation. This effectively made the role of banks functionally obsolete, especially when we refer to the major requirements of money. Although, distributed issuance causes Bitcoin to be volatile, a difficult feature to have for money. So, new technological developments have resulted in the introduction of stablecoins: cryptocurrencies pegged to a fiat currency in order to minimize volatility. Future content will dive deeper into blockchain, Bitcoin and stablecoins.

Blockchain Basics

Blockchain was a very popular word in 2018. At times, it was used as a new and fresh buzzword to get people's attention. Although, there are real use cases for this new form of technology. A blockchain is a distributed ledger of transactions composed of a peer-to-peer network. The motivation that led to the creation of blockchain technology was the need for less centralized control. It was first introduced alongside Bitcoin, the first cryptocurrency to prevent the need for a trusted intermediary to verify transactions. Instead of a single, central entity verifying activity (like a bank), a blockchain has programmed nodes that ensure only the truth passes through. This may seem a bit complicated, so let's break things down to provide clarity.

Peer-to-Peer Network

One component of a blockchain is its peer-to-peer network. This is an architecture of computers that contribute computing resources for a particular purpose. By sharing the workload of the network in a collaborative manner, a central service is not necessary to operate. Every peer has the same amount of power and privilege. These peers are attached to the network and known as "nodes." The most common use case of peer-to-peer networks has been sharing files on the internet. P2P file sharing has been popular because it allows computers to send and receive files simultaneously.

When you visit a typical website to download a file, the website acts as a server, allowing your computer to receive the file. This is a one-way road. The owner of the website has complete control over the existence of the file. If the same file is downloaded in a peer-to-peer network, the download is performed differently. When the download button is clicked, the file is downloaded to your computer in multiple parts from many other computers connected to the network. At the same time, the file is uploaded to the network by your computer, allowing others to download it. A peer-to-peer network is supported by the power of distributed nodes.

Distributed Database

The component that differentiates a blockchain from a common P2P network is the public ledger that all nodes work together to maintain. When data enters the network, the same information is sent to all of the nodes on the network. These nodes keep copies of the blockchain, a distributed and immutable public ledger that records all transactions. These transactions involve things like money, files or information. Nodes can leave the network because others already have a copy of the public ledger. When a new node joins, a connection is immediately made and the information shared. Therefore, power distribution allows for verification abilities and bias-free management.

There are many different blockchains that exist. Blockchains are programmed software that fundamentally work similarly, but have certain differences. They are popular in cryptocurrencies because they prevent the need for a bank to verify transactions are uniformly correct. Although, they have many use cases such as: giving people control of their medical data, rewarding content creators for their work and ensuring legal contracts are completed correctly and efficiently. To further understand how a blockchain works, let's focus on the oldest and most popular one: Bitcoin.

Example: Bitcoin's Blockchain

A person submits a transaction to the Bitcoin network. It is grouped with other similarly-timed transactions into a block and nodes ensure the values inside are correct. A miner, or a full node with significant computing power, solves uniquely hard math problems to add a hash to the block. This hash is required for it to be added to the blockchain and indicates the order of each block over time. Then, it is announced to the whole network for cross checking. If confirmed, the miner receives a block reward for contributing computing power to operation of the network. All nodes are informed to update their public ledger. This process, called Proof of Work, is specific to the Bitcoin blockchain. Other blockchains may have different ways of processing input for their decentralized system.

In summary, a blockchain is a public ledger that exists on a distributed database. It is constantly updated as new transactions are confirmed. A blockchain continues to operate efficiently and transparently because it cannot be changed in a malicious or incorrect way. This is because each block contains hashes that link to past blocks. Blockchains provide a revolutionary, decentralized way to securely verify and record a history of transactions, preventing the overarching control of a centralized entity.

Introduction to Mining

The word mining is easily associated with unearthing precious metals using a big, metal pickaxe. There's no guarantee of finding something valuable, but the work is worth the possible reward. Mining cryptocurrencies involves a similar balance of work and luck in order to earn. Although, its application serves several purposes that makes it extremely unique. In order to understand how mining maintains a blockchain, we'll focus on Proof of Work mining first implemented by the Bitcoin network. Since its creation, other cryptocurrencies have been created, containing similar or vastly different mining systems. Still, Bitcoin remains the most notable coin in the crypto space. So, let’s see how it works!

Comparing Systems

The U.S. dollar is backed by a central bank called the Federal Reserve. It regulates the production of new money and prosecutes the use of counterfeit currency. Payment processing companies, like Mastercard and Visa, manage a network of global transactions. These central authorities have become the industry standard as they’ve become deeply ingrained in day-to-day operations. In contrast, Bitcoin is not managed by a central authority. It is backed by millions of computer nodes recording transactions and ensuring accuracy just as the Federal Reserve and payment processing companies do. Miners are globally distributed, creating a secure network that cannot be altered by a select few.

It’s extremely difficult to duplicate paper money. Not only are the raw materials unattainable, but a system of serial numbers ensures uniqueness. Pair this with central authorities that monitor the flow of money and you have a system acts to verify transaction of the physical dollar. Digital information can be reproduced easily without some type of verification process. Therefore, the Bitcoin mining system ensures “double spend” is impossible by always ensuring the party sending money has what they’ve stated. A copy of a token cannot be sent while the original is kept, serving the same purpose of government and payment processing entities.

Part 1: Creating the Hash

Using the Bitcoin network, users create cryptographically secure transactions and broadcast them to the Bitcoin network. Computers, known as nodes, verify the transaction is sound by comparing it against their record. If the spender has the funds they wish to send, the transaction proceeds to the mining pool composed of more capable nodes called miners. Users that choose to pay a higher transaction fee, creating a greater miner incentive, receive priority in the mining pool. Miners participate in a process known as Proof of Work in order to add a block of transactions to the blockchain. The transaction data of each block is passed through a hash function to generate a 64-digit hexadecimal number, called a “hash.” This creates all the information inside secure. Each past block contains a permanent hash that cannot be changed.

The Bitcoin blockchain is composed of blocks that have been put together in sequential order. Think of it like the strongest Jenga tower ever where you can't remove a block from the bottom. No individual is able to spend their holdings twice. Any network tampering would alter the hashes contained throughout, causing an immediate mismatch and rejection. This continually recorded history record prevents the possibility of dishonesty, an integral feature of an accountable and decentralized monetary system.

Part 2: Guessing the Nonce

Mining a block requires the miner to produce a value (a nonce) that, after being hashed, is less than or equal to one used in the most recent block accepted by the Bitcoin network. This is known as the "target hash." In order to do this, miners use their computing power to quickly cycle through possible solutions by trial-and-error. Think of it like trying to guess your friend's birthday and checking your answer with his mother. Miners compete against each other to find the solution in order to receive a reward for their effort. Miners guess values at a rate reflective of their physical structure. If a computer contains more advanced parts, it will be able to cycle through nonces at a quicker rate. Once a miner guesses the correct nonce, it is broadcast to the mining network. Other miners use it to create a hash and verify correctness before adding it to the blockchain. Finally, the entire network is made aware of the block addition. A copy of the blockchain is updated across all record keepers, miners and nodes. Miners proceed to solve the next block in queue.

Miners compete to solve the problem so they can earn an established block reward and attached transaction fees user paid. Remember, these vary according to how quickly users want their payments to be processed. The current block reward is 12.5 Bitcoin, released by the code of the blockchain algorithm to the miner that helped to verify the blockchain. To ensure there is always competition, the difficulty to solve each block is adjusted based on the amount of miners connected to the Bitcoin network. As more miners join the network, mining difficulty increases to ensure balance. In contrast, if computational power is taken off the network, mining difficulty will decrease. Think of it like this: if many people apply to a job, the competition will be difficult. If few apply, the difficulty lessens.

Additionally, the block reward is programmed to halve every time 210,000 blocks have been added to the blockchain. This ensures that Bitcoin is a deflationary and scarce resource that, according to the psychology of markets, should increase in value over time. Although the difficulty and reward size will decrease, the value of Bitcoin is expected to increase alongside or beyond the time of mining. Overall, Proof of Work mining allows for a monetary system that does not require any third party (bank) to record and verify transactions.

Bitcoin Basics

You may have read about it online and I'm sure your friends have asked you about it. According to most, it's a new kind of money that uses the internet and doesn't need a bank. That's a good start, but only scratches the surface. Bitcoin is reinventing the way money is spent, received and managed. In a world where central authorities control all monetary exchange and do little to protect the privacy of their users, a new kind of money sounds pretty cool. But, it's hard to trust something new. An important component of money is credibility and trust that it will always be valuable. So, what's the best way to learn about Bitcoin and how it poses to democratize the global financial system? Keep reading!

Bitcoin’s Origin

The Global Financial Crisis of 2008 wasn’t pretty. It was caused by banks issuing mortgage loans to those that couldn’t fulfill repayment. Without any profit return as a result of defaulted payments, banking institutions were on the brink of failure and the housing market spiraled downwards. The United States government issued new money to bailout the banks, giving the economy new life, but not without a cost.

This further devalued the Dollar and caused lasting effects on the finances of many. All while powerful executives became even wealthier. It was proof that monetary policies were favorable to the rich and banks could not be trusted to manage an entire financial system.

During the financial turmoil of 2009, an unknown individual(s) named Satoshi Nakamoto published the Bitcoin whitepaper to a cryptography email list. It described a trustless system that could transmit value without the need of a bank. Bitcoin’s introduction was calculated and purposeful. It initially gained popularity within the computer security space and slowly grew beyond it.

A few years later, Satoshi disappeared from discussion, confident that the future was bright. Satoshi’s identity still remains unknown, contributing to the mystery and openness of the Bitcoin ecosystem. Bitcoin continues as an open source project, welcoming all those that want to contribute. Its community of developers continues to grow exponentially with the Bitcoin Foundation ensuring its positive development.

What exactly is Bitcoin?

Bitcoin sounds weird and complicated. A “bit” of a “coin,” what does that mean? It’s not as complex as it may seem. Bitcoin is the first decentralized electronic cash payment network that enables value to be transferred peer-to-peer. Unlike traditional payment networks that require management and approval from banks and government, Bitcoin operates without a centralized authority. Instead, a public and shared ledger, called the blockchain, stores activities and balances.

Thousands of internet-connected computers across the globe, known as nodes and miners, maintain the network by verifying transactions are correct and recording history. Its distributed layout does not require trusted intermediaries, allowing individuals to send and receive money anywhere in the world at anytime. If I wanted to send Bitcoin to a friend in Asia on a Saturday, I could. I don’t have to wait until banks open on Monday or pay significant fees to convert my money from Dollars to Yen. Bitcoin allows anyone to manage their own finances without oversight or approval.

Inner Workings

Instead of a central authority governing operation, Bitcoin is supported by a vast network with no single failure point. To get a better idea of how Bitcoin works, let’s run through a typical transaction. Anthony wants to pay Sarah, the waitress, for his meal using Bitcoin. In order to conduct their transaction in Bitcoin, they will use a “wallet” on their smartphones (we'll get into wallets in future sections). Similar to a typical wallet you carry around, a digital wallet stores Bitcoins securely using cryptography.

Instead of using a plastic card to pay, Anthony uses this smartphone's camera to scan a unique QR code on Sarah's phone. This recognizes the restaurant's Bitcoin address, similar to an email address. Anthony types in the amount his meal cost, including the tip, and presses send. Behind-the-scenes, this creates a digital signature that is the mathematical equivalent of a traditional signature. This let's the Bitcoin network know Anthony is the one sending the payment.

After pressing send, the transaction is broadcast to the nodes maintaining the network. Nodes are important because they maintain a copy of the blockchain to ensure there is an accurate record of history. Anthony's transactions, in addition to others that occured at a similar time, are grouped together into a "block." Special nodes, called miners, verify his signature and that he has the amount of Bitcoin he wishes to spend by comparing it against the record. Then, they compete against one another to solve a complex mathematical puzzle, called Proof-of-Work.

The first miner with the correct solution broadcasts their block to rest of the network. Other miners verify the solution and if confirmed, the block is added to the blockchain. Additionally, the winner is compensated with a reward composed of newly created Bitcoins and transaction fees. At the end of this process, Sarah will see Anthony's payment in the restaurant's wallet. The speed of the transaction is dependent on the amount of activity on the Bitcoin network. Voila, a complete Bitcoin transaction!

Comparing the Competition

Bitcoin has several features that make it superior to modern day global currencies. Due to its infancy, it is also subject to growing pains that challenge its growth. Here's the breakdown:

Advantages:

Autonomy: There are no usage restrictions for digital cash, giving the user complete control. No individual can suspend or confiscate your Bitcoins.

Savings: Wire transfers and international remittances are costly. Instead of paying steep middlemen fees, Bitcoin transaction fees are extremely nominal when operation is optimal.

Decreased Risk: Merchants that accept Bitcoin don't fear unscrupulous "charge-backs" since transactions are permanently recorded on the blockchain.

Transparency: An immutable history of transactions ensures no manipulation is performed by an individual or organization.

Access: With nearly 2 billion people without access to financial services, Bitcoin enables everyone to participate in a global economy of scale.

Deflationary: There will only ever be 21 million Bitcoins in existence, preventing the possibility of an artificial increase in money that causes inflation.

Disadvantages:

Volatility: Due to decreased standardization and scarcity, Bitcoin price tends to fluctuate sometimes making it difficult to efficiently use for payment.

Acceptance: Since Bitcoin is only 10 years old, almost no major retailers currently accept it as a means of payment.

Scalability: Still growing in popularity and use, the limited infrastructure of the Bitcoin network impacts the speed and efficiency of transactions.

Bitcoin has many advantages, but there are several clear disadvantages compared to traditional currencies. Although, these are all obstacles that can be overcome with more time and greater development. Bitcoin is a promising new monetary experiment to completely democratize the global financial system.

Entry to Ethereum

Bitcoin was growing. The idea of digital currency was growing. Pioneers began to see the promise of blockchain technology beyond Bitcoin's single focus as a payment platform. This led to the introduction of Ethereum, a digital computer for executing peer-to-peer contracts. It was a foundation that allowed developers to build trustless technology that disrupted many industries. Instead of only being a payment platform, Ethereum (ETH) was focused on becoming a computing platform powered by smart contracts that could be built upon. Let's peel back the layers of Ethereum to understand its history, technology and widespread implications.

An Idea Was Born

Vitalik Buterin become intrigued by blockchain technology when he first joined the Bitcoin community in 2011. As he explored the industry further, co-founding Bitcoin Magazine, he began building a platform that extended beyond Bitcoin's financial use case. In 2013, he released a technical report, known as a whitepaper, describing a technology that expanded upon the functionality and use cases of Bitcoin. Ethereum would be a "world computer" that allows complex programs to operate without the need of a central entity by using smart contracts.

Vitalik's idea of Ethereum drew attention. Soon, a core team of all-star developers was formed to build Ethereum. In July 2014, they launched a crowdsourcing campaign, known as an Initial Coin Offering (ICO). Individuals purchased tokens, hoping they would appreciate in value just like the stock of a company. They were able to successfully raise $18 million to kickstart development.

The Ethereum team established four major releases for the project, each with additional features that would allow the project grow. These were named: Frontier, Homestead, Metropolis and Serenity. In July 2015, a year after their fundraise, the Ethereum network went live with Frontier. This was the beta stage of the technology, uncovering network problems before a more stable release. In March of 2016, Homestead was released to the public.

Hacking the DAO

Nearly a year later, the DAO (decentralized autonomous organization) was created to fund projects building on Ethereum with the ecosystem's token: ether. The public invested ETH in return for DAO tokens, used by the community to vote on which projects were worthy of funding. The DAO introduced an alternative venture capitalist model where the general public could benefit financially from the success of a project built on Ethereum.

Only a month after its creation, users exploited a vulnerability in the DAO to steal 3.6 million ETH. For unknown reasons, they did not continue draining funds. The Ethereum community took control of the issue and agreed that they would initiate a hard fork in order to return the lost funds. In essence, this rolled back transactions to the point before the hack. This resulted in a new blockchain, retaining the name Ethereum, and the original blockchain, named Ethereum Classic.

Many believed this violated the basic principles of blockchain technology relating to permanency. Regardless, the Ethereum community moved past this event and continued building its vision. This time, security and legal clarity were a major priority.

Tokenization

As the Ethereum ecosystem grew, so did the price of ether. In 2017, it rose nearly 113,000%. This drew the attention of many investors and developers. Ethereum was slowly becoming a full-service platform to build out the decentralized web with new applications and token ecosystems. In October 2017, the third stage of the Ethereum platform rolled out: Metropolis. The major goal of this part of the roadmap was to ensure widespread adoption.

Thousands of new projects began building on top of Ethereum, creating utility tokens labeled as ERC-20. They could be traded on exchanges and used within decentralized applications. This completely diversified the cryptocurrency ecosystem. Ethereum allowed new technology to grow and develop using its tools and system.

Flexible Programming

Satoshi wrote Bitcoin in C++ in order to ensure consistency and security. These were essential features of the Bitcoin network. Although, this coding language was also limited in flexibility. Ethereum sought to be the flexible alternative, with much greater options and use cases.

Ethereum is a programmable blockchain. It expands beyond the functionality of Bitcoin, allowing developers to create operations of any complexity. This takes shape as decentralized blockchain applications, also known as dApps.

Ethereum is a distributed Turing machine labeled as “Turing complete.” This means that with unlimited memory available, anything can be accurately calculated. Developers can create contracts that solve mostly any reasonable computational problem. This is essential for the sophisticated logic and complex operations that smart contracts require. Additionally, this logic can be translated between languages, making the creation process more welcoming and flexible.

Operation

Smart contracts run on the Ethereum Virtual Machine (EVM), an emulation of a computer system. It handles the internal state and computation. The code inside is completely isolated and unable to access external points. This ensures security and efficiency. The code is the backbone to smart contracts that live on the blockchain and only initiate when programmed requirements are met.

Similar to Bitcoin, Ethereum includes a peer-to-peer network protocol. This involves the exchange of ETH between wallets. Nodes connected to the network maintain and update the blockchain database. They run the EVM and execute instructions identically. Ethereum is known as the “world computer” because of this kind of distributed computational structure. Decentralized consensus allows Ethereum to tolerate fault, ensure no downtime and immutably store data to the blockchain.

Transactions

The transactional structure of Ethereum’s ecosystem uses its native token “ether” or ETH. Those that send transactions pay “gas,” transaction fees that are required for operation. Gas is composed of ether and its amount is reflected by the activity on the network.

Currently, Ethereum implements the same PoW mining structure as Bitcoin. Ethereum transactions are broadcast to the network and grouped into blocks. Miners compete to verify and solve a complex math problem in order to add this block to the blockchain. They are rewarded with ETH for contribution of resources to the network.

Serenity is the next and last phase of development and has one key principle. It’s main goal is to ensure scalability by switching the Ethereum network from proof of work to proof of stake. This would drastically reduce power consumption of the network. We are still waiting for the Serenity upgrade to occur.

Conclusion

Computers and their infrastructure allow for powerful actions that have extended our abilities as humans. They have completely transformed environments like voting, governance, marketplaces and finance. Although, further digitalization has also resulted in increased complexity. This increase has led to both programmatic and third party reliability issues. The need for more efficient operation without a trusted intermediary has become increasingly valuable.

Like programming languages, developers can use Ethereum for applications that facilitate interactions between peers across a network. Exchanges of any complexity can be carried out with simplicity, reliability and autonomy. The power and flexibility of an optimal Ethereum network provides developers with tools to create a new, decentralized internet. It puts power back in the hands of individual creators, allowing them to create powerful decentralized and trustless applications.

Stablecoins 101

A useful currency should be a unit of account, medium of exchange and a store of value. Although, most cryptocurrencies continue to be an inefficient store of value due to their natural volatility. Most businesses don't want to accept cryptocurrencies as a means of payment because it could be worth less not long after the transaction. The same is true for workers, negative fluctuation in the worth of a salary is difficult to tolerate. Overall, the volatility of common cryptocurrencies make it difficult for common transactions.

The price of traditional cryptocurrencies is determined by supply and demand shown on exchanges. In contrast, stablecoins are a unique type of cryptocurrency with a fixed price and varying levels of decentralization. Stablecoins mix features of fiat and cryptocurrencies to create a stable alternative.

Why are they important?

Unlike most cryptocurrencies, stablecoins are not traded for profit. They are meant to replace traditional fiat and used for common consumer actions such as paying for groceries. Their fixed price makes them a viable option for this. Unlike traditional currencies, like the Euro or Franc, stablecoins allow global access to financial services.

Currencies are unique to their geographic region. Most countries have their own form of paper money. The US Dollar remains one of the strongest currencies due to a powerful economy and democratic government. Its inflation is very minimal compared to other smaller economies, like Venezuela and Nigeria, where they experience hyperinflation in excess of 20% a year. This results in a currency whose value is less than it actually states. As inflation increases, more money is required to have the same purchasing power.

It is extremely difficult, and sometimes impossible, for individuals of these countries to hold and transact in US Dollars. Many simply do not have access to financial services at all. Stablecoins provide global access to a digital currency that has a stable price and decreased inflation. This allows anyone to participate in a financial system, avoiding restrictive controls and unstable monetary systems.

Additionally, stablecoins allow cryptocurrency-based capital markets to form. With a stable currency, individuals are able to use and invest without fear of drastic inflation. A lender and borrower are able to use the blockchain to transact a loan with limited currency risk. The formation of these services is essential for a robust, digital financial ecosystem.

How do they work?

Two of the most popular stablecoins are fiat-collateralized and crypto-collateralized. Let's take a look at what these mean:

Fiat-collateralized

This stablecoin structure incorporates strong traditional currencies, usually the US Dollar, making it the least decentralized. Each stablecoin is backed by a corresponding unit of a fiat currency. A trusted third party, usually a bank, holds the same amount of US Dollars as stablecoin that exists. This currency peg allows for a stable value equal to a single Dollar per stablecoin. The most popular fiat-collateralized stablecoin is Tether, highly used by crypto traders to avoid volatility.

This type of stablecoin is easy for common consumers to conceptualize and provides a 1:1 match with USD. It circumvents traditional financial system barriers and fees that exists. This includes overdraft fees, transfer fees, hour transfer restrictions, etc.

There are several negative features of fiat-collateralized stablecoins. They require several third parties to hold and audit the fiat collateral to ensure proper backing. Although they are an improvement from fiat currency itself, the crypto-aspect of decentralization is non-existent. Therefore, third parties involved still have exceptional power over operation and levels of transparency.

Crypto-collateralized

Instead of using a fiat collateral, this stablecoin utilizes cryptocurrencies. Since the underlying cryptocurrency, or basket of cryptocurrencies, can be volatile, they are pegged at a ratio greater than 1:1. This requires a significant amount of collateral to be held. A popular example of this form of stablecoin is MakerDAO.

This form of stablecoin has several benefits. Since all transactions are conducted on-chain, like with Ethereum, a third-party is not relied upon as a custody solution and auditors are not necessary for transparency. This is much more decentralized than a fiat-collateralized stablecoin, resulting in greater user power and privacy. Additionally, there is greater flexibility in stablecoin units and liquidity for exchange.

There are also several downfalls to crypto-collateralized stablecoins. The complex selection of a basket of cryptocurrencies for backing incorporates unsure stability and security. This poses a major problem for a stablecoin which is meant to ensure a constant and stable value. Additionally, these are not capital or organizationally efficient. They are more decentralized, but less efficient than fiat-collateralized stablecoins.

Conclusion

Stablecoins are extremely experimental. The goal is to create a digital currency that maintains a stable value, but is not susceptible to control by third parties. It is currently unknown what the stablecoin that accomplishes these goals will look like. As interest in stablecoins continues to increase, greater research will be performed into risk and rewards. Although, it can be agreed that a successful implementation of a stablecoin would drastically alter the financial ecosystem as a whole.

Smart Contracts 101

Typically, trusted intermediaries verify requirements are met before allowing an exchange to proceed. In a decentralized environment, a middleman isn't relied on to authenticate. Instead, we can use smart contracts. These allow an exchange to occur by comparing programmed rules to the input received. There's no need to trust a human, just unwavering code. Ensuring correctness without a third party is an extremely valuable component of blockchain technology. So, how do smart contracts actually work? Let's have a look!

What is a smart contract?

Nick Szabo, a cryptographer, first defined the concept of smart contracts in 1993. He described them as:

"A set of promises, specified in digital form, including protocols within which the parties perform on the other promises."

There's no guarantee a contract, or a specified agreement between people, will execute correctly without a permanent assurance. Basically, a smart contract is a contract that self-executes if certain conditions are met. They are made possible by using the cryptography present in public blockchains. Overall, smart contracts ensure exchanges made are verifiable, observable and enforceable.

What can they do?

Trust is a mechanism of requirement. There's no need to trust someone if you don't have to. Smart contracts have a place anywhere that involves agreeance from two sides with a clear, traceable account of what happened. This includes things like real estate sales, legal contracts and monetary loans.

Let's say you're sending money to someone in exchange for their digital collectible. You have to send them money, then wait for it to be received without any absolute guarantee. A smart contract simplifies this entire process by completely removing the need to trust anyone. Instead, a system that utilizes smart contracts would recognize cryptocurrency sent for the purchase and immediately release the digital collectible to the new owner. This occurs because the requirements specified were met: the buyer sent money to the seller in the exact amount they specified. Smart contracts are always accurate and traceable. Woah, now that's a smart program!

Are they safe?

Whether you're exchanging money or a house deed, all digital transactions need to be safe and secure. Since smart contracts utilize the blockchain, they gain its inherent benefits. This includes being stored on the blockchain where data is immutable. Therefore, no one could maliciously alter the smart contract. Even if they tried, the blockchain would reject their entry since it doesn't properly match the record. The system is programmed to strictly adhere to what it knows is right and wrong. And since blockchain operation is supported by nodes, there's no single point of failure like a centralized entity.

Removing the need of a trusted intermediary makes contracts inherently safer. Execution is programmed into the system and does not require reliance on any human contribution. This makes using smart contracts not only more efficient, but cost-effective as well.

The Future of Smart Contracts

Smart contracts are an exceptional example of the intelligence that trustless technology can provide. They are creating new ways to do business. By using them, different business operations can interact without fearing a problem amongst trusted individuals. Instead, cryptographic code ensures complete accuracy and traceability.

Smart contracts set the groundwork for new innovation. Business sectors can be disrupted by using new technology without sacrificing security or transparency. A whole new kind of transactional infrastructure can be built by using smart contracts.

Businesses interested in future-proofing themselves should seriously consider blockchain technology that incorporates smart contracts. Just think, buying and selling could occur without using any third parties. Joe could purchase a new phone and his money would be placed in escrow. Once he confirms all is well with the device, the money would be automatically released. Smart contracts incorporate reliability, something essential to the growth and operation of businesses.

I know one thing, the digital future sure sounds smart.

The Lightning Network

Blockchain technology is very new. We are still in the very early days of development. Current blockchains have many benefits, but almost all still experience significant scaling issues. Individuals are deterred from sending and receiving cryptocurrencies due to slowness and increased transaction fees. So, how do we solve this issue to ensure millions of people are able to transact efficiently? Luckily, there's a major solution that's being created to solve the non-scalability of Bitcoin: The Lightning Network. Let's dive into what it is and how it works.

The Problem

It is clear that an efficient, global monetary system must be able to support billions of people. Lightning Network (LN) was first proposed by Lightning Labs, a company led by CEO Elizabeth Stark. They are creating an open protocol for scaling and speeding up blockchains. It is mainly being used for the Bitcoin blockchain, but the technology can be applied to any blockchain.

The current implementation of Bitcoin only allows for 1MB blocks. Remember, those things that get added together to make the blockchain. Therefore, Bitcoin can only successfully process up to seven transactions per second. Visa, a payment processing network that supports much of the world's transactions, can process up to 50,000 transactions per second. Lightning Network can potentially scale Bitcoin to millions of transactions per second, reducing transaction fees to cents.

How does it work?

Lightning Network is based on a technology called payment channels. It utilizes smart contracts to ensure the network is decentralized and risk-free to anyone involved. A two-party payment channel is created when both parties create a multi-signature transaction on the blockchain, with at least one party committing funds. This initial transaction takes about 10 minutes to open a channel. With the channel's allocated funds, participants are able to conduct future transactions instantaneously. These instantaneous transactions are composed of passing signed transactions back and forth, spending from the original entry. Lightning Network allows these channels to be created on top of Bitcoin, which means faster exchange at a lower cost.

The Lightning Network is one big mesh of people. In this type of arrangement, many different people are connected to each other. Samantha has a channel open with Hakeem, who has a channel open with Karishma and so on. Since the Lightning Network uses smart contracts and multi-signature verification, Samantha doesn't have to trust Hakeem in order to send funds to Karishma. Since cryptography is built into the protocol, she just uses Hakeem as a bridge. This allows funds to be instantaneously routed from Samantha to Karishma without needing to open a direct channel between them. If the funds don't successfully reach their intended destination, the smart contract automatically refunds the original sender.

Why is it important?

As you can see, the Lightning Network is a high potential solution to solving the scalability issues of blockchains. As more channels are opened, transaction speed increases and transaction fee decreases. At scale, it would allow millions of transactions per second, exceeding the capability of modern day processing networks.

The Lightning Network is such a promising solution because it prevents the need to change the underlying protocol of Bitcoin. Block size does not have to be increased in order to accommodate more transactions. Larger block sizes require more powerful miners to process transactions. Capping block size at 1MB maintains a high level of decentralization since more miners are able to contribute to the network. Overall, the Lightning Network drastically increases the potential use cases of Bitcoin.

Want to support the Lightning Network? You can either download a LN mobile wallet or create your own routing hub to help process transactions (either the full unit can be purchased or you can make your own).

Blockchain Disruption

Industries are always ripe for new innovation. There are many industries that blockchain can potentially disrupt. There's one where it could have a widespread impact: medicine.

Health records increase situational awareness by providing an in-depth history of patients. Medical personnel operate at the highest capacity when they are able to securely disburse and source health information. The current centralized health record system is predominantly digitized and remains insecure as organizations transmit data between incompatible platforms. Many companies use single data warehouses to store all their information. This data pile is not only inefficient, but vulnerable to attack in the brutal internet of things environment. The equipment and applications used to store patient information remain susceptible to breaches and feature an extremely low level of interoperability.

The current centralized ecosystem disregards the user as the driver of the process. Providing patients with validation credentials creates informative access to personal health information and the possibility of preventative medicine through user empowerment. This alteration to connectivity could spur the incorporation of reactionary medicine. In a realm where immediacy and efficiency are crucial, the current electronic health record system must be altered. That's where blockchain can save the day.

Digitalization

The digital revolution has given birth to an environment of interconnectedness. The shift from offline to online has brought about a new era of engagement and liberation. Information sent and received in the current age of computers is highly susceptible to security breaches. Credit card information is stolen every day through the infiltration of the commonplace centralized systems currently in place. Trusted third party entities have failed in their ability to protect sensitive user information.

Decentralization can protect this information in a world where the internet of things continues to grow. Alongside security, a movement towards efficiency and user empowerment continues to grow, leaving centralized entities stirring. Interoperability streamlines processes, giving the user overall control of the data they create.

Blockchain Benefits

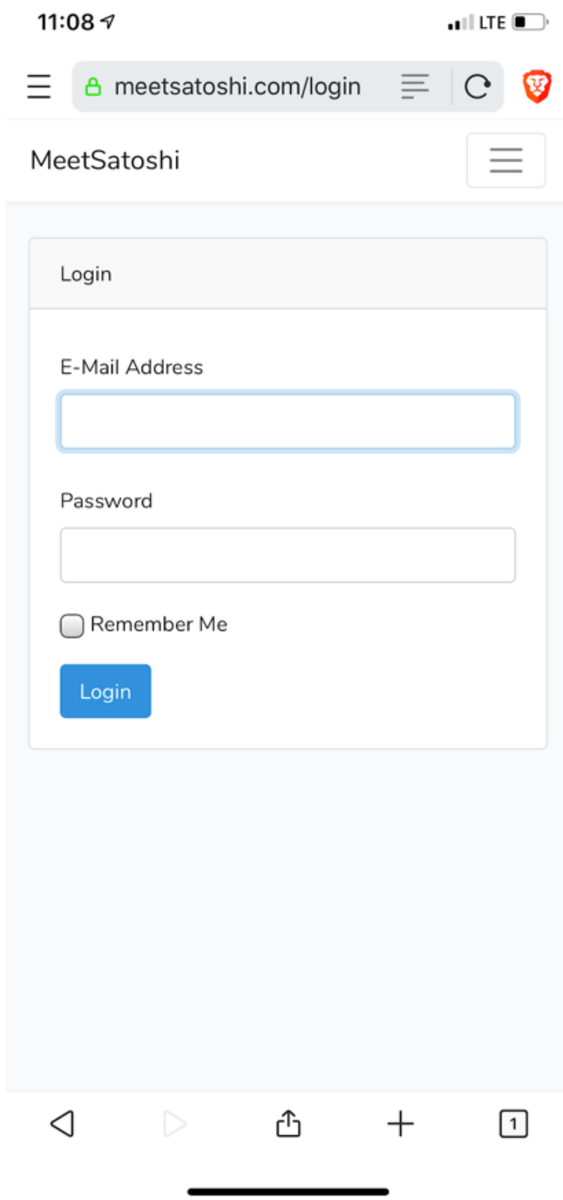
The age of the internet has created an online ecosystem that has altered the way interactions are made and data is exchanged. Research and events have uncovered the dangerous inefficiencies associated with the centralized atmosphere in place. The desire for the integration of blockchain technology grows stronger every day. Blockchain is a decentralized ecosystem where transactions can be performed in a secure, reliable and user-centric way.

The transition of medical records to the blockchain can facilitate exceptional improvement in the exchange and storage of sensitive health information. The distribution of health information across a distributed network, containing multiple gateways of system and user validation, will allow for a high level of security and user empowerment. This transition will ensure a high level of privacy and increase patient awareness for a potential movement towards preventative medicine.

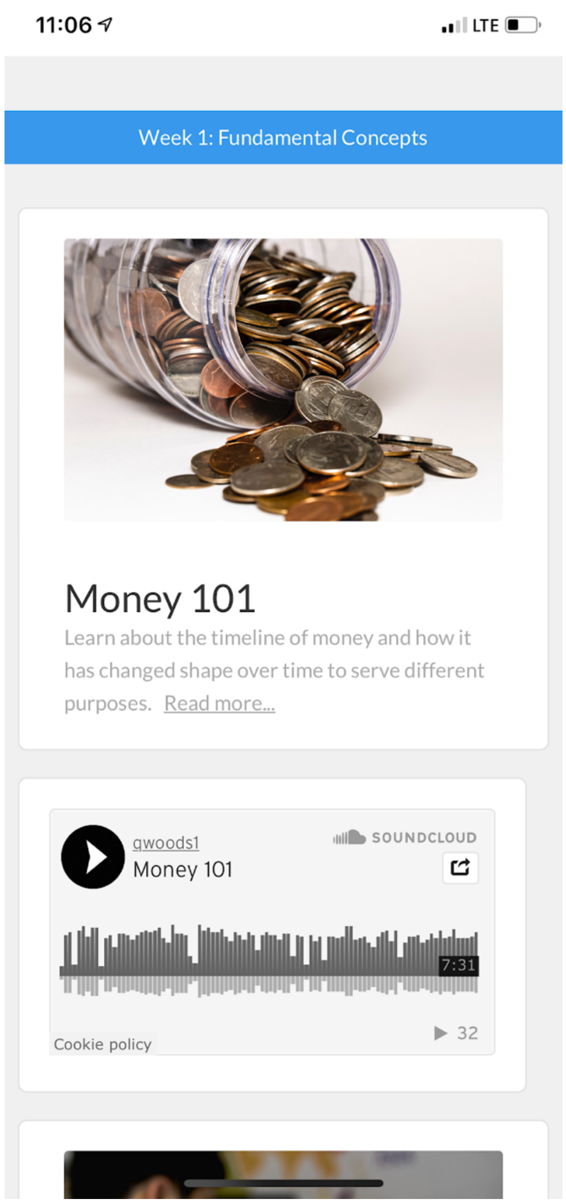
Beyond the user-focus, Blockchain-based medical records will allow for one shared data source. Differing platforms spread across the complex health network will remain personalized while sharing the same foundation for information storage. A high level of interoperability will increase the capability of medical organizations in their interactions and exchange of pertinent health information. This will lead to more immediate care, a valuable ability in the medical realm. The transition of electronic health records to the blockchain is the next step towards a decentralized system that prioritizes the patient, security and assembly.

APPENDIX G

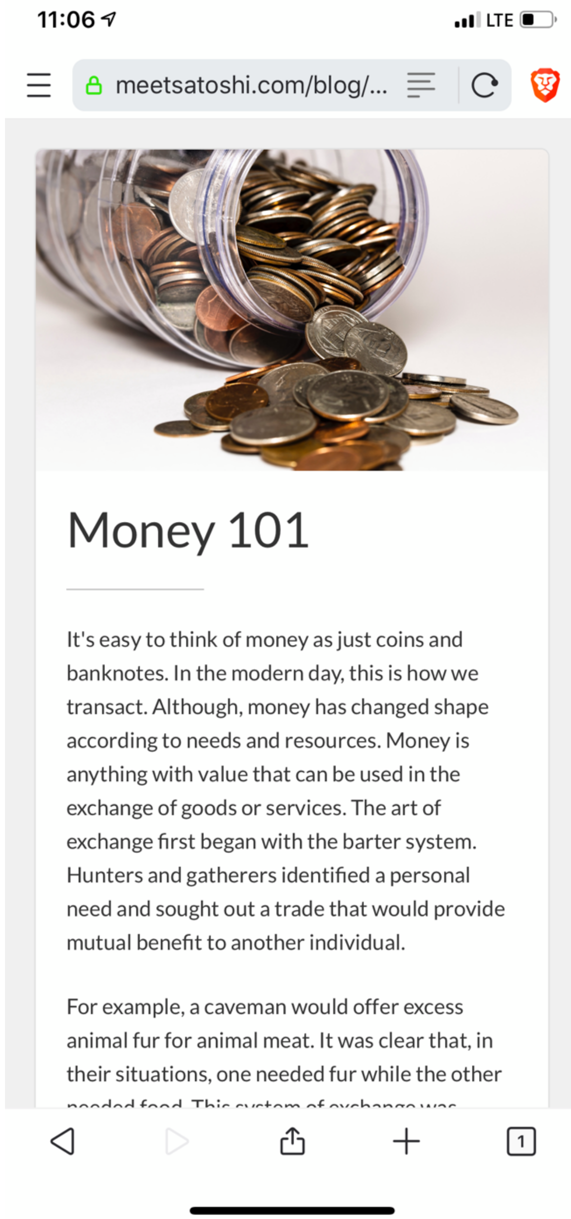
SCREENSHOTS OF TESTING WEBSITE



Login Portal


11:06
LTE
Week 1: Fundamental Concepts
Money 101
Learn about the timeline of money and how it has changed shape over time to serve different purposes. Read more...
qwoods1
SOUNDCLOUD
Money 101
7:31
Cookie policy
32

Homepage



Money 101

It's easy to think of money as just coins and banknotes. In the modern day, this is how we transact. Although, money has changed shape according to needs and resources. Money is anything with value that can be used in the exchange of goods or services. The art of exchange first began with the barter system. Hunters and gatherers identified a personal need and sought out a trade that would provide mutual benefit to another individual.

For example, a caveman would offer excess animal fur for animal meat. It was clear that, in their situations, one needed fur while the other

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