Prototyping With Blockchain: A Case Study For Teaching Blockchain Application Development at University

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Abstract. Blockchain technology is believed to have a potential for innovation comparable to the early internet. However, it is difficult to understand, learn, and use. A particular challenge for teaching software engineering of blockchain applications is identifying suitable use cases: When does a decentralized application running on smart contracts offer advantages over a classic distributed software architecture? This question extends the realms of software engineering and connects to fundamental economic aspects of ownership and incentive systems. The lack of usability of today's blockchain applications indicates that often applications without a clear advantage are developed. At the same time, there exists little information for educators on how to teach applied blockchain application development. We argue that an interdisciplinary teaching approach can address these issues and equip the next generation of blockchain developers with the skills and entrepreneurial mindset to build valuable and usable products. To this end, we developed, conducted, and evaluated an interdisciplinary capstone-like course grounded in the design sprint method with N=11 graduate students. Our pre-/post evaluation indicates high efficacy: Participants improved across all measured learning dimensions, particularly use-case identification and blockchain prototyping in teams. We contribute the syllabus, a detailed evaluation, and lessons learned for educators.

Keywords: blockchain application development, design sprint, capstone course, interdisciplinary, case study

1 Introduction

Cryptocurrency and blockchain technology has gauged the interest of researchers and practitioners alike. Over 65 million Bitcoin wallets [2], and over 15.500 cryptocurrencies [6] exist. Ongoing development efforts aim to advance blockchain technology further. Smart-contract blockchains established themselves among the most active projects – e.g. Ethereum, Solana, Cardano, and Polkadot list among the ten highest-valued projects [6]. Supporters view the technology as transformative [8] and data from Coinbase's shareholder letter indicates growth rates comparable to internet user adoption in 1998 [5]. Particularly the ability to *read, write and own* is perceived as a paradigm shift enabling a new generation of internet applications, and with it, the so-called *Web3* [1].

However, research from the field of Human-Computer-Interaction (HCI) reveals that existing blockchain applications suffer from usability issues (e.g [11–13, 17, 34]), are difficult to understand [12], and home to frequent misconceptions [23]. One cause for this is that many blockchain applications address use-cases that do not derive clear advantages for the user from using blockchain technology. While scholars in software engineering have started exploring concepts for education (see e.g. Xu et al. [35] and Labouseur et al. [21]), we argue that an interdisciplinary approach is necessary to address these issues. For the next generation of blockchain developers to be able to truly build valuable and usable products, they need to be able to evaluate blockchain use-cases w.r.t technical feasibility (engineering), value-creation (entrepreneurship), and user experience (human-computer-interaction).

To address this gap, we developed, conducted, and evaluated an interdisciplinary capstone-like course with N=11 graduate students. During a 5-day period, the participants ideated, developed, implemented, and deployed a smart-contract trading-card game, allowing users to collect and trade researchers as non-fungible tokens (NFT). The course curricula builds on the design sprint framework [19]. It is, to our knowledge, the first course combining blockchain application development in an interdisciplinary setting. Our evaluation shows that the course is well-perceived by participants and enables participants to distinguish use cases (not) suited for the technology. We distill lessons learned for educators and discuss the benefits and advantages of an interdisciplinary approach to teaching.

2 Background & Related Work

Our work draws from several strands of research, most notably from design sprint methodology as framework for designing our course.

2.1 The Potential of Blockchain and Web3

Together with Bitcoin [25] the world was introduced to the technology powering it – the blockchain – in 2008. Since then developer activity has been steadily growing [7] and many projects were started to improve the original design. Ethereum, started in 2013 was the first blockchain that enabled the development of decentralized smart contracts [3]. Newer projects – e.g. Cosmos, Solana, Polkadot – have come forward to overcome Ethereum's limitations, particularly speed and transaction throughput. This new generation of blockchains, providing transactions at instant speed and low transaction costs, is believed to bring along the third stage of the web: Web 1.0 offered internet users the possibility to *read* content. Web 2.0 added the possibility to *write*, enabling rich interactive internet applications. Web3 now adds the possibility to *own* digital assets on the internet. Practitioners believe this read-write-own paradigm will enable a new class of internet applications with a sizable potential for innovation [1, 13].

2.2 Blockchain Applications and Their Usability

Cryptocurrencies and blockchain started to become a topic of increasing interest in the research community [13]. A recent literature review, reveals that the usability of blockchain and cryptocurrency applications was shown to be problematic [13]. Users face many threats [10], cryptocurrencies are hard to understand, and misconceptions (e.g. keys, fees, and anonymity) are common [14, 23]. Even though onboarding can support users' meaning-making process [11], first-time users struggle with the complexity of the technology [12]. Particular the identification of use-cases in which blockchain can truly provide value seems to be difficult [15]. Trying to address this, there are some approaches outside the university context trying to engage laymen in participatory design activities [18,29,31]. While other technology domains have been exploring novel teaching concepts spanning across disciplines (e.g. Kopeć et al. presented insights from a VR hackathon [20]) we did not find any for blockchain.

2.3 The Design Sprint Framework

To develop our course we used the design sprint framework as a theoretical basis [19]. Related to design thinking [30], it formalizes a user-centered product development process. While design thinking does not define clear boundaries with regards to resources and time [32], the design sprint framework integrates the different aspects of design thinking into a five day program. One sprint is composed of five phases – map, sketch, decide, prototype and test – each completed in one day [19]. We identified a few research publications using the framework at university, however, non related to blockchain. Sarooghi et al. propose the design sprint as process model to integrate design thinking into entrepreneurship education [33]. Larusdottir et al. present the a two-week long user-centered design course [22] and highlight the importance of balancing "talking and doing". Sari and Zulaikha adopted the framework to include more prototype development time in UX design courses and evaluated the approach in a longitudinal study [32].

2.4 Summary

Blockchain technology, particularly smart contract development in the context of Web3, offers the potential to build new types of applications surrounding the notion of ownership. While research has started to explore blockchain teaching, no teaching concepts integrating software engineering, entrepreneurial thinking, and user-centric methods have been reported so far. This is problematic as use-case identification for blockchain applications is a core challenge that requires a multidisciplinary perspective. The design sprint framework offers a starting point to integrate these aspects and design a blockchain application development course at university-level that equips students with the skills to create both useful and usable blockchain applications in the future.

3 Course Description

Our goal was to integrate technical, entrepreneurial, and human-centered elements into an applied blockchain application development course in an effort to enable students to identify problems and find valuable solutions. The resulting course heavily relies on collaboration and interaction between students of different disciplines, with the objective to empower participating students to:

- identify and evaluate use cases for blockchain applications
- apply user-centered methods to define product requirements
- prototype and develop a functional decentralized application

The course differs from typical software engineering courses in its focus on interaction and collaboration between disciplines. It differs from typical hackathon formats by providing a structured syllabus providing guidance throughout the course.

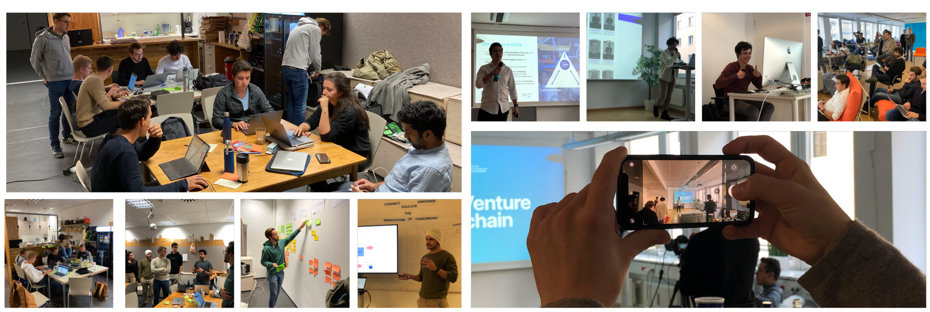

Fig. 1. We present a case study of an interdisciplinary course on blockchain and smart contract application development at a German university. The image shows impressions of the course (left) and of final presentation (right).

We used the design sprint [19] as theoretical starting point to design the course. We added a kickoff session two weeks prior to its start, in which participants were introduced to the blockchain, were assigned into teams, and received homework assignments. The second phase was a 5-day-long hackathon-like course adapting the design sprint method which finished with the public launch of the prototype. Figure 1 provides impression of the course (printed with permission of the participants).

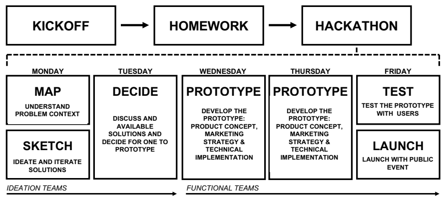

Fig. 2. The procedure of the overall course and the hackathon-week based on the design sprint framework.

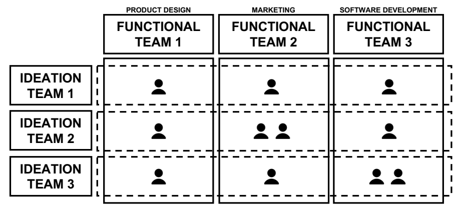

Fig. 3. The team assignment: At the kick-off each participant is assigned to one functional and one ideation team.

3.1 Participants & Team Assignment

We recruited N=11 graduate students at our university. The syllabus was shared in advance for interested students to sign up and receive 2 ECTS for successful participation. We did not require participants to have prior knowledge about blockchain. The final sample consisted of four students enrolled in computer science or data science majors and four business administration majors. The average age was 24 years. One participant identified as female, ten as male.

At the kickoff, participants were assigned to *functional teams* (product design, marketing, software development) based on educational background and personal preference. The most experienced student in each functional team was selected as team-lead to organize communication between teams. To evaluate use cases, participants were additionally assigned to cross-functional *ideation teams*, each responsible to cover a different problem space (c.f. Fig. 3).

3.2 Course Structure & Procedure

The structure of the course is inspired by the design sprint framework [19], which defines a 5-day process for user-centered prototype development. We adapted the original method to fit our educational goals: We introduced a kickoff event and an up-front homework assignment, combined the *map* and *sketch* stages into one day to accommodate an additional *prototyping* day, and launched a functional prototype at the end of the week (c.f. Fig 2).

1. **Kickoff Workshop:** Participants were introduced to the course structure and received an introductory lecture about blockchain. In a moderated session they ideated for broad problem spaces addressable with blockchain in the "university" context. The final clusters were each assigned to one ideation team for further evaluation as homework assignments.
2. **Homework Assignment:** Each ideation team had to evaluate and prepare three cluster-specific problems addressable with blockchain. Additionally, each functional team had to prepare a presentation on state-of-the-art product design, marketing, or software development approaches for blockchain. Hence, the homework integrated the *map* phase of the design sprint.
3. **Design Sprint Hackathon:** The hackathon took place between October 11th and 15th 2021. During the first two days, participants worked primarily

in their ideation teams. Once prototyping started on day three, teams organized primarily around their functions, albeit collaborated flexibly when necessary. Each day stand-up meetings were held before lunch and dinner. A backlog of tasks was tracked with sticky notes. As support five experts from industry and academia were accessible throughout the week.

(a) **Monday – Map and Sketch:** The functional teams generated a task backlog for the week. The ideation teams presented their ideas and used the day to evaluate and decide on three candidate ideas by the evening.
(b) **Tuesday – Decide:** The ideation teams further detailed the ideas. In functional team meetings ideas were evaluated w.r.t. feasibility and impact. After feedback from industry experts, the final idea was selected.
(c) **Wednesday – Prototype:** Organized by functional teams, participants started product design, partner acquisition, and prototype development.
(d) **Thursday – Prototype:** In addition to the ongoing development user testing of the early prototype and preparation of the launch event started.
(e) **Friday – Test and Launch:** The prototype was tested, finalized, deployed, and launched. The hackathon concluded with a demonstration of the functional prototype in front of an in-person and livestream audience.

4 Results & Evaluation

In total 11 graduate students participated in the course. 55% participated in a blockchain related course at university before, two in a blockchain hackathon. 73% participants owned one or several cryptocurrencies. Participants rated their interest in blockchain technology with ideological aspects (mean 4.455), followed by technological curiosity (mean 4.364), and financial opportunities (mean 3.636). For example, P6 stated: "*I am interested in blockchain because I'm always curious about new technologies and trying to see what benefits they can bring*".

4.1 Developed Blockchain Application

Over the course of the week, the students narrowed their idea pool from initially nine down to one final idea and implemented it. Figure 4 shows two screenshots of the final prototype: *Profini*, "The Professors' Panini", is a card trading platform inspired by the children trading game. It features university professors and researchers as tradable NFT cards. The idea arose from the increasing distance participants felt between professors and students as university education became virtual during the COVID-19 pandemic. The cards are meant to humanize the academic faculty, increase their visibility, and foster interaction with students. The prototype implemented the trading card logic in a smart contract, deployed on the Polygon blockchain [27]. The frontend uses ReactJS [9] and integrates with web3.js [4] to access the smart contract. The prototype was launched with a public event at the final day with in-person attendance and via livestream. In total 25 researchers could be collected at launch. By connecting a Metamask [24] wallet on the website users could purchase booster packs, each containing three random cards. Owned cards can be sent directly to other wallets or traded on marketplaces such as OpenSea [26].

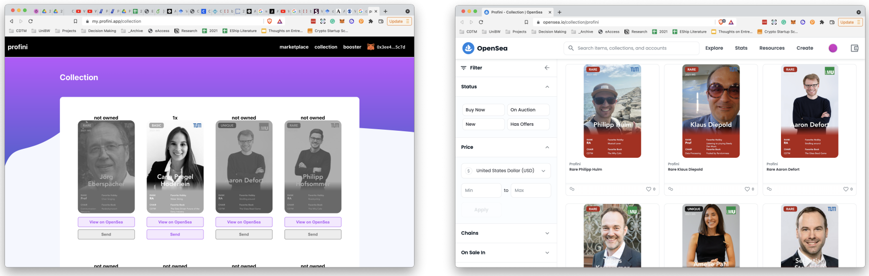

Fig. 4. Screenshots of the final prototype – *Profini*. The web application (left) showing available and owned NFT trading cards after connecting the Metamask wallet. Owned trading cards can be traded on Opensea (right).

4.2 Learning Outcomes

To evaluate the educational impact we conducted a pre-/post assessment. Numerical values were collected on Likert-Scales from 1 (Totally Disagree) to 5 (Totally Agree). We introduced the questionnaires before the start of the week and the day after its completion. The first questionnaire also collected demographics, previous experience, interest in the blockchain space, and motivation to participate in the course. The second questionnaire also evaluated participants' overall perception of the course. Both evaluated the following dimensions:

1. perceived potential of blockchain technology
2. perceived difficulty to engage with blockchain technology
3. perceived skills and abilities related to blockchain application development
4. perceived intention to engage with blockchain technology in the future

Perception of Blockchain The course had a measurable effect on the students' perception of blockchain technology. Table 1 and 2 provide an overview. After the course participants were on average more convinced that blockchain will have a positive societal impact (+0.273), less doubtful of its technological potential (-0.364), and more confident about its future adoption (+0.818). The course also had the desired effect on the perceived difficulty to use (-0.364), learn (-0.091), and prototype with (-0.455) blockchain technology.

Table 1. The perceived perceived potential of blockchain technology before and after the course.

measure	Pre	Post	Change
positive_impact_on_society	3.909	4.182	+0.273
limited_technological_potential	2.818	2.455	−0.364
future_use_by_everyone	3.727	4.545	+0.818

Table 2. The perceived difficulty to use, learn, and interact with blockchain technology before and after the course.

measure	Pre	Post	Change
difficult_to_use	3.636	3.273	−0.364
difficult_to_learn	3.273	3.182	−0.091
difficult_to_prototype_with	3.273	2.818	−0.455

Skills and Abilities We evaluated nine skills and abilities around blockchain use and development. Along all of them the course had a positive impact, though some improved more than others. Table 3 provides an overview. While general tasks (create and use wallet, send and receive cryptocurrency, interact with dapps, find learning resources) were rated rather high to begin with, they showed improvement driven by learnings from the less experienced participants. While participants' confidence to identify suitable use cases for blockchain technology increased by 0.455 points, they felt even more confident (+0.909) to spot those use cases where blockchain would not bring benefits. Students' confidence to prototype with blockchain on their own remained the lowest score before and after the course (2.818 and 2.909) while their confidence to prototype with a team increased by 0.455 points to 4.273.

Future Engagement After the course students felt motivated to continue interacting with the technology. Table 4 provides an overview. There is a notable increase (+0.455) in the intention of students to engage with online blockchain communities. The intention to buy cryptocurrencies (+0.273), interact with smart contracts and Web3 applications (+0.273), and enroll in further blockchain education (+0.182) increased less pronounced.

Table 3. The self-rated skills & abilities related to blockchain application development before and after the course.

measure	Pre	Post	Change
explain_blockchain	4.000	4.364	+0.364
create_wallet_and_buy	4.636	5.000	+0.364
send_and_receive_crypto	4.636	5.000	+0.364
interact_with_dapps	4.182	4.818	+0.636
eval_suitable_use_cases	3.818	4.273	+0.455
eval_nonsuitable_use_cases	3.636	4.545	+0.909
find_learning_resources	4.364	4.455	+0.091
prototype_alone	2.818	2.909	+0.091
prototype_with_team	3.818	4.273	+0.455

Table 4. Questions about planned future interaction with different blockchain related aspects before and after the course.

measure	Pre	Post	Change
engage_blockchain_com	3.636	4.091	+0.455
enroll_in_blockchain_edu	4.182	4.364	+0.182
buy_cryptocurrency	4.545	4.818	+0.273
interact_with_web3	4.545	4.818	+0.273

4.3 Overall Course Evaluation & Student Perception

To understand participants' experiences we asked several questions about the overall course perception in the post-course questionnaire. To quantify their overall perception of the course, we asked them to indicate on a scale from 1 to 10, "*If we offered this course again, how likely would it be that you recommended it to your friends?*". The Net Promotor Score (NPS) [16] calculated from their answers is 81.818, which can be considered "world-class" [28]. To elicit qualitative feedback we asked two open questions, "*What are the main learnings for yourself?*", and "*If there was one thing you could change, what would it be?*". The reported learnings turned out to be quite unique to each participant. They included technical aspect (i.e. how to develop a smart contract), use-case specific aspects (i.e. when it makes sense to decentralize), method related (how to use user story maps), or process related (how important communication between teams is). There was, however, a clear indication what participants would like to change. Seven participants (63%) suggested to re-allocate one day from the earlier ideation phases to prototyping and implementation.

5 Discussion

Our study set out to shed light on whether an interdisciplinary course would be an appropriate format to teach university students about blockchain application development. We found that the design sprint framework offers a sound theoretical underpinning for creating such a course. Our assessment further indicates a high efficacy of the approach: Across all measured learning dimensions participants' perception improved.

5.1 Educational Impact

Our evaluation shows a positive educational impact of the course across all measured dimensions. Particularly, teaching goals that benefit from interdisciplinary exchanges – e.g. prototyping with a team (+0.455), identifying suitable (+0.455), and identifying not suitable (+0.909) use cases – improved substantially. We attribute much of the learning effects to the applied and interdisciplinary environment created by the course structure. Provided with autonomy, equipped with diverse skills and abilities, and different degrees of knowledge on blockchain technology, students were encouraged to quickly learn from and teach one another. As such, they were required to collaborate closely to solve problems together and compromise with one another to overcome conflicting viewpoints. These results are naturally limited by the small sample and the study design. Future research should evaluate the impact at larger samples, over longer time, and with appropriate control groups. Nonetheless, we believe that the syllabus and evaluation are valuable for educators to design applied blockchain education in the future. Beyond blockchain, our case study shows that the design sprint method is a useful framework for creating applied teaching concepts bridging gaps between disciplines.

5.2 Lessons learned

We share four key lessons learned from the field study:

1. **Diverging from the traditional design sprint timeline can increase sense of achievement.** While the design sprint provided a good theoretical basis to design the course, in future we would allocate more time to the development of the prototype to give students the opportunity to engage with the technology in more depth. To enable a sense of achievement we recommend to aim at creating a functional prototype by the end of the week

and have participants organize a launch event around it. To allow for more time for the actual development, we suggest to conduct the *map* step entirely before the start of the week and begin implementation one day earlier.

2. **Interdisciplinary team compositions can promote a more holistic understanding.** We observed a beneficial effect of students being from different study programs, as their diverse experiences fostered discussion, collaboration, and facilitated a more holistic understanding. The course empowered students in their skills and abilities to explain blockchain (+0.364), create a wallet and buy crypto (+0.362) or interact with dapps (+0.636). We believe that the exchange within an interdisciplinary peer group was a significant factor for the positive development, as the wide range of knowledge fostered a broader understanding of blockchain through peer-learning.
3. **Domain constraints can provide necessary focus for use-case ideation.** Restricting the initial brainstorming to the university context was an important frame to guide students' ideas. This constraint allowed students to focus their ideation and allowed practicing to differentiate useful use cases (+0.455) from not useful use cases (+0.909) in a specific domain rather than on a theoretical level. Ideally, contextual constraints are set beforehand by the organizers, for which some experience with both the domain and the technology is beneficial.
4. **Decision autonomy can enable joint problem solving.** As organizers, we took on a moderating role – managing the process and refraining from engaging in decisions. The respective teams entirely owned goal setting, project management, and direction of their product. This autonomy enabled active discussions and empowered students to learn from and teach one another to overcome challenges. As a result, students felt more comfortable prototyping with blockchain. Yet, the effect was greater for prototyping with team (+0.455) as opposed to prototyping alone (+0.091), which supports our idea of joint problem solving being valuable.

6 Conclusion

This work contributes (1) the syllabus of an interdisciplinary blockchain application development course integrating engineering, entrepreneurial, and user-centered elements, (2) a detailed evaluation of its learning outcomes, (3) and lessons-learned for educators. We found that the design sprint framework offers a sound theoretical underpinning for creating such a course. Our assessment further indicates a high efficacy of the approach: Across all measured learning dimensions participants' perceptions improved. We report the syllabus of the course for other educators to benefit from it and discuss lessons learned for future iterations. We believe that the course design can serve as a blueprint to run engaging practice-oriented courses on blockchain application development. For the wider community of engineering educators, the course can be adapted to different engineering contexts (e.g. artificial intelligence) integrating technology education with entrepreneurial thinking.

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