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Legal and Smart! An Exploratory Case Study on Understandability of Smart Contracts

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Abstract

This paper addresses the understandability of smart contracts when compared to their traditional legal form. Our method is an exploratory case study conducted with 36 students in information systems (IS). We conclude that smart contracts written in Solidity language are understandable by users with a background in programming languages such as Java and Python. The main advantage of smart contracts is the clarification of complex and/or disperse clauses in legal agreements. A key disadvantage is the lack of support to contextual information. An hybrid of the two forms can contribute to the clarification of legal contracts, but also raises challenges to keep both versions synchronized. In the advent of blockchain-related implementations, our work contributes to the adoption of smart contracts in IS courses and prepares futures research to evaluate the understandability of smart contracts by IS experts, legal advisors, and end users.

Keywords: Smart contract; legal contract; understandability

1. INTRODUCTION

Contracts are getting smarter! The vision of a smart contract was introduced in 1994 by Nick Szabo (Szabo, 1994). This author defined it as a computerized transaction protocol with user interfaces that facilitate the contracting process (Szabo, 1997). The use of technology (hardware and software) to implement new forms of contract agreements promised to reduce the "*mental and computational transaction costs*" in the intervention of third parties (Szabo, 1997). This seminal work discusses the key differences and similarities to traditional legal contracts, their "*inanimate paper-based ancestors*" (Szabo, 1997). However, the use of smart contracts in that era was far from being a reality (Omohundro, 2014).

Over a decade had passed when Satoshi Nakamoto published a disruptive article about Bitcoin, the first successful implementation of Blockchain technology (Nakamoto, 2008). The achievement of Bitcoin led to consideration the use of more sophisticated forms of contracts (Omohundro, 2014; Zheng, Xie, Dai, Chen, & Wang, 2017). Smart contracts became a reality, as pieces of code stored in a Blockchain that execute automatically under certain conditions (Zheng et al., 2017).

Smart contracts can "facilitate, execute and enforce the terms of an agreement between untrusted parties" (Alharby & van Moorsel, 2017). They are distinct from traditional contracts in that they are fully digital and their performance is independent of third parties, allowing lower transaction costs (Alharby & van Moorsel, 2017; Macrinici, Cartofeanu, & Gao, 2018). The interest in smart contracts is increasing, with instances already being used in several areas such as "financial services, life sciences and healthcare to energy resources and voting" (Macrinici et al., 2018).

Either in physical or in digital forms, contracts are essential to rule how the society works and their understandability is a major concern. As stated by Howe and Wogalter (2012) "[p]*eople are frequently asked to sign contracts and other legal documents that are meant to bind them to specific rules. But does the average citizen really understand what they are signing*"? If people do not understand the contents of a contract, they cannot comply with the rules imposed by them (Howe & Wogalter, 2012). Accordingly, the authors proposed a checklist to improve the legal contracts regarding their comprehensibility (Howe & Wogalter, 2012).

Howe and Wogalter's (2012) is even more important nowadays, as smart contracts loom. When searching for "understandability of smart contracts" we found the scientific literature to be scant. Therefore, our study aims to analyze the understandability of a smart contract when compared to a legal contract. Our research adopts the definition of understandability as the ability to comprehend something, taking into account a person with "*reasonable knowledge*" about the subject and "*the willingness to study the information*" ("Business Dictionary," 2019). Accordingly, we have formulated the following research question:

RQ1. Can information systems students understand the content of a smart contract as they do that of a legal contract?

An exploratory case study (Yin, 2003) was the selected research approach to address this question. We conducted a pilot case with finalist undergraduate students in informatics engineering, during an information systems (IS) course. We drew up a legal contract and its corresponding smart contract version using the Solidity language ("Solidity — Solidity 0.5.8 documentation," 2019).

The understandability of smart contracts by IS students is valuable for teaching and for implementing both, physical and digital agreements to rule transactions in many sectors of the economy. Answering our research question can also provide clues about the possibility to introduce artefacts created with the Solidity language in IS courses.

The remainder of this paper is structured as follows. Next, we describe the research approach, detailing how we obtained the data. Subsequently, we analyze the results. Section 4 draws on the analysis of the collected data to discuss the understandability of legal contracts and smart contracts.

Section 5 describes our strategy for future work. The paper closes summarizing the main conclusions and the study limitations.

2. RESEARCH APPROACH

We chose an exploratory case study approach (Yin, 2003) to investigate the understandability of smart contracts when compared to traditional legal contracts. Case studies enable researchers to acquire an in-depth understanding of a topic within a specific context (Zainal, 2007). According to Yin (1983), a "*single-case study may be conducted as a prelude to further study such as the use of case studies as exploratory devices or such as the conduct of a pilot case*". This paper reports a pilot case with IS students that we plan to expand to other participants, namely experts in information systems and law.

In this research we used Ethereum and Solidity ("Solidity — Solidity 0.5.8 documentation," 2019). Ethereum is a popular Blockchain platform that extends its functionality with smart contracts (Buterin, 2013). Solidity ("Solidity — Solidity 0.5.8 documentation," 2019) is the programming language used in the development of smart contracts to Ethereum Virtual Machine (EVM). Solidity is a high-level programming language based on C ++, Python and JavaScript ("Solidity — Solidity 0.5.8 documentation," 2019), compatible with other blockchain platforms. We selected this language to create a smart contract with the same characteristics of a legal contract commonly used in e-commerce.

All the students that participated in our research know how to code in several languages, but they had no previous knowledge of Solidity language. Therefore, this pilot case revealed a dual interest to (1) validate and improve a questionnaire about the understandability of legal/smart contracts, and (2) evaluate the potential of introducing smart contracts created in Solidity in IS courses with computer science background.

3. DESCRIPTION OF THE EXPERIMENT

To assess how the understandability of traditional legal contracts and smart contracts compares, we asked a jurist to draft a sample of the former and then translated it into Solidity to create the latter. The contract regulates the on-line sales of a fictitious wine shop. It includes the (1) identification of the object, (2) information about products and prices, (3) ordering and payment, (4) shipping costs, (5) deliveries, (6) contractual vicissitudes and returns, concluding with (7) the applicable law. The contract is written in Portuguese.

The smart contract version written in Solidity v0.5.8 contains declarations of state variables, functions, function modifiers, events, struct types and enum types ("Solidity — Solidity 0.5.8 documentation," 2019). Our smart contract is composed by:

- 26 variables (store information in the contract);
- 15 functions (executable units of code);
- 6 function modifiers (amend the semantics of functions and can be reused in multiple functions).

We chosed not to include comments in the Solidity code (which is possible, similarly to other programming languages) due to the risks of influencing the comprehensibility of the code with remarks in natural language. The ordering of the functions in the smart contract is the same as the clauses in the legal contract.

Figure 1 illustrates the implementation of one of the clauses in its legal form and in Solidity. The full version of the contracts is now available from https://doi.org/10.6084/m9.figshare.8938517.

Legal contract:

For orders to be sent to the requested address, the option of sending - National Shipping (in case of Portugal) and International Shipping (in case of other countries outside Portugal) must be chosen.

Smart Contract:

```
function definirModoEnvio() public vendedorOuComprador verificacaoIdadeLegal returns (string memory) {

        if (keccak256(abi.encodePacked((compradorPais))) == "Portugal") {
            compradorModoEnvio = "Envio Nacional";
        } else {
            compradorModoEnvio = "Envio Internacional";
        }
        return compradorModoEnvio;
    }
```

Figure 1 - Example of implementing a legal clause in a smart contract

After creating the contracts to use in our research, a survey was chosen to collect the data. Closed questions were included to assess the understandability of the content of the contract in both forms: traditional legal format and Solidity smart contract. The questions addressed the (1) interpretation of the language used in the legal contract (e.g. definition of payment methods), (2) omissions verified in the legal contract (e.g. absence of consequences in case of delivery time failure), and (3) Solidity interpretation (e.g. functions modifiers and require ()). The questions of the survey, the legal contract and the names of variables and functions in smart contracts are in Portuguese, since it is the native language of the participants.

After implementing the questionnaire in Google forms, we have performed a preliminary test with two PhDs in IS, to assess whether the questions were understandable, and to test the data collection

process and possible errors in the online forms. Minor modifications were made to the questions based on their feedback. Finally, the survey was used with the IS students. The survey was conducted during an Information Systems class and lasted approximately 25 minutes. The participants were randomly divided into two groups and each group had access to only one of the forms of contract: legal contract or smart contract. After the survey, the correct answers were presented and discussed with the participants. The next section details the field results of our pilot study.

4. DATA ANALYSIS

We have obtained 36 responses. Seventeen participants had access to the traditional legal contract and nineteen to the smart contract in Solidity. The quantitative analysis of the answers to the closed questions provided hard data about the specific aspects of understandability they address.

This section evaluates the students' answers to seven questions about the content of the contract (the same questions were presented to the students using the legal contract and the smart contract) and a final question about the overall complexity of the contract.

Table 1 summarizes the questions, purpose, and the expected answer.

Question	Purpose	Type Answer	Expected Answer
Q1 Which factor(s) determine the legal age to buy products in the wine shop	Understand a single condition	Multi select multiple choice	Country of residence
Q2 What happens if the buyer lives in a country forbidding alcoholic beverage	Evaluate the lack of information in the smart contract	Single select multiple choice	Not mentioned in the contract
Q3 What are the payment options for a customer resident in Brazil	Understand multiple rules for the same operation	Multi select multiple choice	bank payment slip, paypal, bank transfer
Q4 Calculate the shipping cost for a buyer living in Portugal	Understand a composite rule (formulas)	Short answer	14€
Q5 What is the final condition to allow order fulfilment	Overall understanding of the contract (multiple rules for multiple operations)	Multi select multiple choice	Legal age and confirmation of sale conditions
Q6 After the expedition, if the delivery time takes too long, what the buyer can do	Understand a missing option to a specified operation	Single select multiple choice	Not mentioned, Common law applies
Q7 What the buyer should do when receiving a product that is not compliant	Understand a complex clause and a sequence of actions	Single select multiple choice	Send a message including the reason to complaint and order number
Q8 Evaluate the complexity of the contract	Perception about the complexity of the contract	Unipolar Likert scale	N/A

Table 1 – Questions for the contract understandability

Figure 2 show the percentages of correct answers of each question, separated by group. Answers are considered correct if all the correct options are selected.

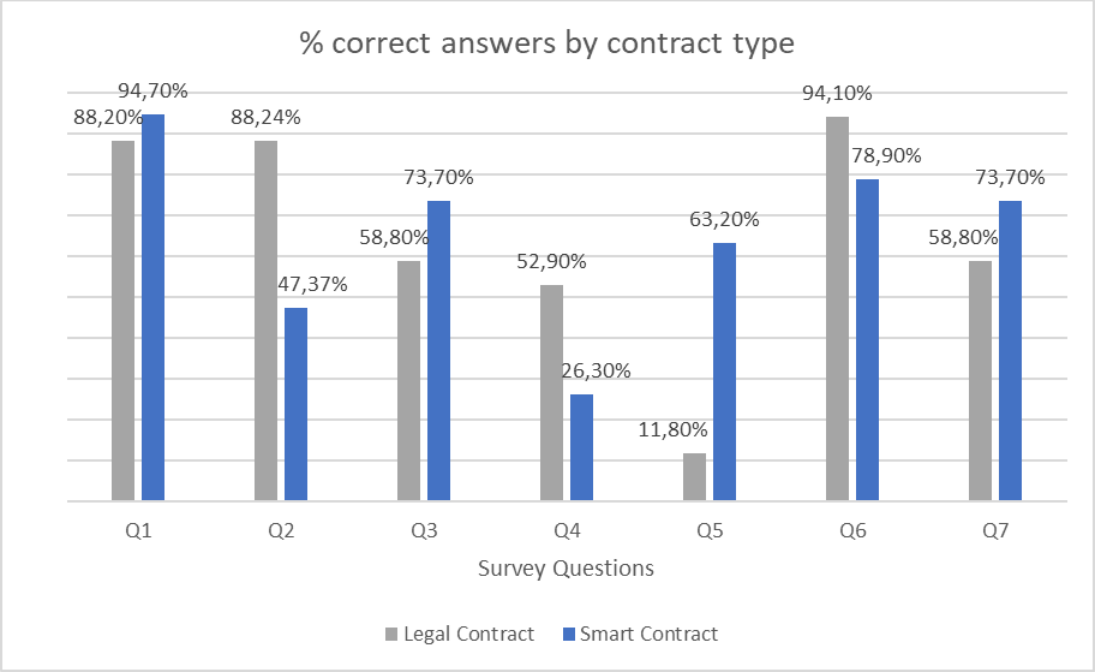

Figure 2 - Correct answers by legal contract and smart contract (%)

The data collected in the two groups reveal differences in the understandability of both forms of contracts, particularly, in Q2 (near 41 percentage points), Q4 (27 percentage points), and Q5 (the highest difference with over 51 percentage points).

In Q1, most participants responded correctly about the legal age for the purchase of alcoholic beverages, with 88% correct answers in the legal contract and 95% among the participants using the smart contract. Near 100% of the smart contract group were able to identify the variable and understood the respective function. This question required to identify a single condition, suggesting that both forms of contracts do not seem to raise specific limitations to the reader, with a small 6,5% of advantage for the smart contract users with programming background.

Q2 evaluates the participants' interpretation in case of lack of information in the contract. The legal agreement includes a disclaimer of the store about the sale of alcoholic beverages to countries that prohibit it. Therefore, it is stated that the Company cannot and does not assume responsibility for sending products to countries that prohibit alcoholic beverages (selling is permitted). However, the smart contract does not have that explicit condition (selling is permitted by omission of a rule that blocks the operation). About 88% of participants with access to the legal contract settled the issue. However, only 32% using the smart contract referred that it was not mentioned and 16% concluded that the order would be made (nearly 48% answered correctly). In the absence of explicit information in the smart contract, a significant number of participants misunderstood the question.

Q3 arose from a doubt of interpretation of the text of the legal contract, when we were developing the smart contract. Participants with access to smart contract responded correctly in 74% of the cases, while only 59% of the other participants were right. In this case, the structuring of the code in Solidity allowed the understanding of the information of the content to be more noticeable than the legal language. This case suggests that the process of translating a legal contract in its smart form can be an opportunity to clarify contract agreements because code functions require specific data to be implemented.

Q4 provided a shipping cost table for a carrier. Both contracts mention the calculation of freight, which is dependent on several factors, including the number of bottles (cost of packaging) and the cost of the carrier. We found that 53% of the participants performed the correct calculation with the legal contract, but only 26% gave the right answer using the smart contract. This may have occurred because the students using smart contracts did not interpreted the (more complex) code in detail, using the cost table as their unique source. Moreover, it was necessary to read the entire function code to answer correctly (the formula was in the last line of code).

The information required to answer Q5 (order fulfillment) is dispersed in the legal contract, in several clauses. Therefore, it allows to assess the overall understanding of the contract by the study participants. Surprisingly, most of the users of the legal contract missed one or more specific clauses for completing the order fulfillment. Interestingly, the smart contract concentrates all the necessary code (modifiers) in the function confirmation of the order, simplifying the interpretations. The results show that 63% of the participants understood the function modifier in the smart contract, contrasting with near 12% in the legal contract group.

Q6 addresses the order delivery process. Both the legal contract and the smart contract refer to the delivery time limits defined by geographical areas; however, they omit the consequence of not complying with the clause. Around 94% of the participants with the legal contract agree on the issue, compared to 79% of correct answers from the other group. Although the difference in this case is only 15 percentual points (p.p.), it is possible that the "result-oriented" focus of reading a program code may guide the participants interpretation. While the users of a legal text may simple state "not mentioned, question solved", the smart contract user may be thinking about "not mentioned, now what can I do with this function?". Nevertheless, the 15 p.p. difference is inconclusive at this stage and can only present hypothesis to explore in future work.

Q7 deals with product returns. This legal clause requires greater analysis and interpretation of the text to understand its full implications. In addition, the smart contract function includes statements such as "requires ()", "modifiers" and specifies "messages" between seller and buyer. The smart contract group reveled a better understanding about the return of products when comparing to the

legal contract group. Similarly, to Q3, the smart contract seems to simplify the understandability of more complex clauses.

The final question was about their perception of complexity about the contract, using a five-point Likert type scale. Each participant answered the question through a scale ranging from simple (1) to extremely complex (5). Figure 3 shows the results of this evaluation.

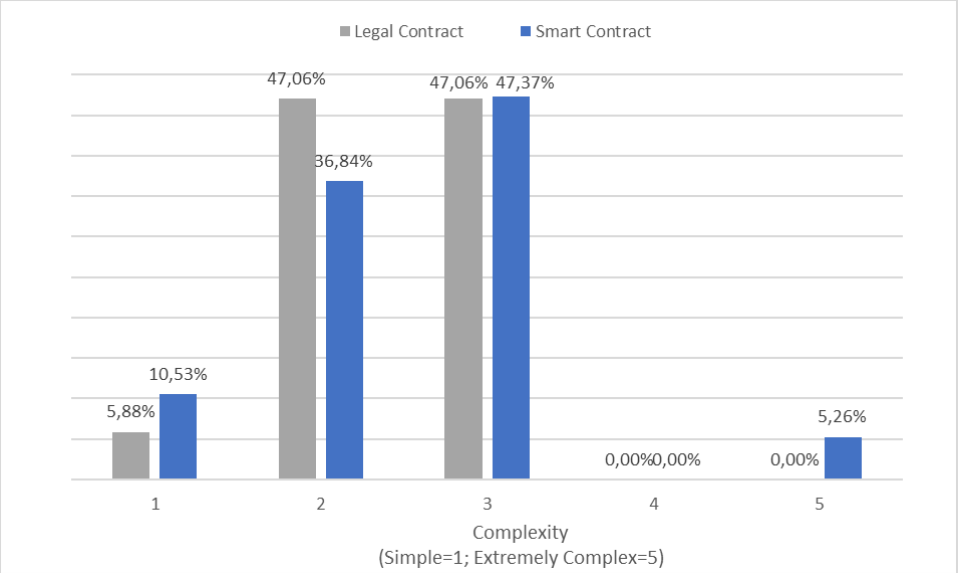

Figure 3 - Level of contract complexity perceived by the participants

The majority of the study participants (using the legal contract or the smart contract) found their contract simple to understand or with little complexity (reaching 89%). The perception of the contract complexity is similar in the two forms of the legal and smart contract. Only one participant in the smart contract group considered the contract extremely complex.

5. Discussion and Outlook

Our pilot case aimed to evaluate the research process and IT tools used to collect and analyze the data about smart contract understandability. It was also an opportunity to generate new ideas and possible lines of research within the scope of smart contract understandability. With this scope in mind, we indicate in this section all the lessons learned in the course of the experiment.

The answers provided to our eight questions suggest that:

- Single variables can be easily identified in both forms of contracts (Q1).
- Some information can be lost when creating smart contracts based in legal text (Q2). For example, a disclaimer may include information that does not implement any function/operation, merely stating that the store “has no responsibility”. The smart contract does not provide support for this information.

- The combination of legal contracts and smart contracts offers an opportunity to enrich the understanding and clarity of the clauses (Q3).
- Q4 suggests that it is important to present specific details in smart contracts when implementing complex calculations. The comments supported by Solidity language can be used to this end.
- Legal contracts with disperse rules can be more difficult to understand, when compared to functions in Solidity that concentrate information and allow a trace between functions (code flow). There are also risks when creating smart contracts using a legal contract as the source (clause implementation in code), because programmers may miss important information (e.g. disperse rules). On the other hand, the translation of a smart contract for the legal form may help in the clarification of complex legal texts and identify ways to improve its readability.

We found advantages and disadvantages in the traditional legal contracts and its smart counterparts. The first conclusion is that the majority of the IS students can understand both contracts. Second, the physical and the digital forms are not exactly the same, as we found in the disclaimer of Q2, completely absent in the smart contract. Therefore, smart contract developers may be aware that it is important to include comments in the smart contract to improve its understandability and avoid conversion errors (e.g. contextual information). Third, as the complexity of clauses increase, the smart contract seems to be easier to interpret. One possible reason is the concentration of variables and conditions in specific functions (and the interaction or flow between multiple functions). However, the translation of complex legal text also poses risks of missing conditions during the code development phase.

The IS students that participated in this research stated that they could understand the Solidity language with their programming background (Java and Python). During a discussion with them, a majority felt that it was not necessary to have a prior class about Solidity to understand the topic of smart contracts. In fact, they felt more interested about the topic of smart contracts when they found that the code was familiar to them. Although these findings are merely indicative because it is a small sample and the results can vary according to the participants background, the preliminary results suggest that it is possible and desirable to show concrete examples of Solidity code when introducing smart contracts in IS courses.

The study participants had no prior knowledge in the programming language that we used. The perceived level of complexity was similar, for traditional legal contract or smart contract. However, we can verify that in cases of omission of information in the smart contract (Q2) and lack of objective statements in the legal text (Q5) most participants did not properly respond to the questions. It is known that legal texts can create interpretation doubts, omit information, or contain ambiguous

language, posing risks to the understandability. Therefore, the interpretation of the legal text during smart contract development is also a risk – discrepancies between the legal version and the digital version. In these conditions, additional research is necessary to ensure the correct alignment and validation between the legal and the smart versions of the same contract.

Smart contracts built with Solidity language allow to include comments. This is a possible solution to provide contextual information (e.g. applicable law, resolution of conflicts). However, this option is not sufficient for implementing online transactions because the end user will not be able to see smart contracts source code and, even if it was possible, the readability would be problematic.

On one hand, the legal contract can provide a better description of the context (e.g. regulations that justify specific rules such as the taxes that we found in our case). On the other hand, the smart contract highlights the rules with higher impact for the stakeholders (complex clauses become clearer). Additional studies are necessary to understand how using both physical and digital forms can improve contract understandability. One possibility is to extend each form (legal/smart) to include the benefits of the other, but it is also possible to consider an integrated version. There are challenges to address in the combined use of the legal and the smart contract, adopting a different language and serving the purpose of specific professionals (e.g. legal advisors and IT experts). An integrated form of contract needs to be accessible to experts with different backgrounds and, simultaneously improve compliance to the contract conditions, protecting all the interested parties.

It is possible to develop a tool that maps traditional legal clauses with smart contract functions, assisting in the integration efforts. This tool could have the functionalities to assess the compliance of both versions (checking if some clause is missing or if it is contradictory) and convert one form of contract in the other. Moreover, this tool could be used to update the content of the contracts or providing alerts to the IT department (if a legal contract changes) or to the legal department (if a function code changes). Another possibility is to select one of the contracts as the main source (e.g. the smart contract) and create a tool that interprets the functions and present the content in a form that is accessible to non-technical users. Nevertheless, there are also challenges. Mapping legal and smart content creates another potential point of failure or manipulation that must be carefully evaluated. For example, errors in the conversion tool or potential interference in its code poses severe risks for contract integrity and needs security actions to mitigate the problem.

Based on the discussion of the results, we refined the research process, the IT tools (questionnaire questions and examples of contracts) and identified three main stages for future research. In the first stage we will focus on the main players in this interconnection between smart contracts and legal contracts: a group of experts in (1) IT and (2) law. The next survey will obtain a higher number of responses and also includes focus group sessions to examine and validate the results of the survey. In the second phase, we plan to extend the analysis of the study of understandability to the general

public. This part of the study is particularly relevant to online commerce and the implementation of contract agreements that comply to (1) digital platforms, and (2) legal regulations. The last stage corresponds to the development of a tool to support the understandability of smart contracts. Figure 4 shows the research process that results from this pilot case.

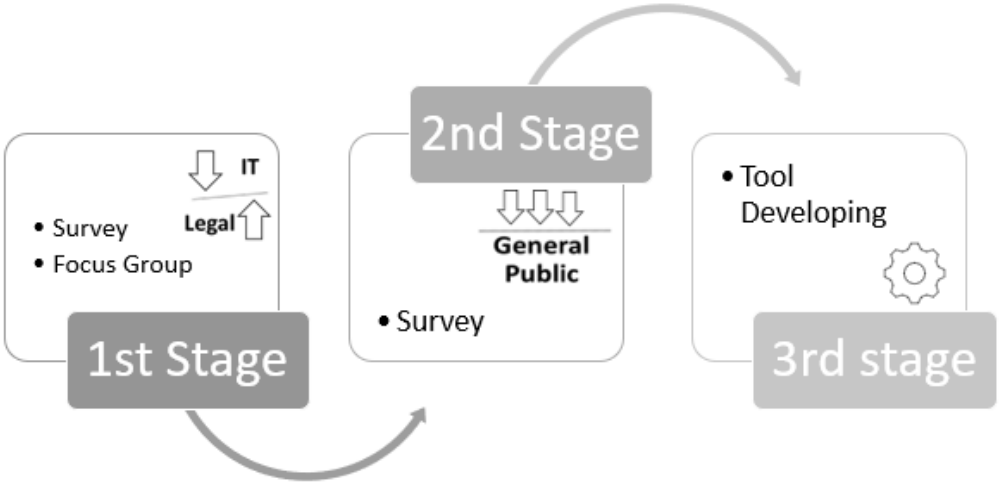

Figure 4 - The 4 phases of the research process

Despite the several opportunities for future research, this pilot study already provided interesting findings to teach smart contracts in IS courses and insights about the understandability of Solidity language to the future informatics engineers. In the next stage of the research we will present both contracts to the participants in a sequence, to understand if the access to both forms of legal and smart contracts has advantages. If we find advantages in that approach, it could be interesting to create training material for IS students that includes both forms of the contract to simplify the understanding of the legal clauses and the code to implement it in the digital form.

6. CONCLUSION

We presented a pilot study about smart contract understandability among IS students with a background in informatics engineering. The findings suggest that the students (with knowledge in Java and Python) may be able to understand a smart contract written in Solidity. The answer to our research question is positive. Our research also allowed to test and improve the data gathering tools to evaluate smart contract understandability among other respondents, namely, experts in IT (e.g. software developers that need to translate legal contracts in code or implement smart contracts in online platforms) and law (e.g. legal assessors that need to evaluate smart contract compliance and alignment with legal contracts). Several opportunities for future research are put forward, aiming to improve the teaching of smart contracts in IS and to evolve smart contract understandability in the growing market of blockchain.

There are limitations in this research. First, this is the first stage of our research about smart contract understandability. It was important to evaluate how IS students understand smart contracts (code structure and legal meaning) and to prepare our next steps, but additional respondents are necessary due to the low number of responses obtained. For future work it is proposed a change to the survey that includes a qualitative analysis to complement and validate our findings. Second, we selected specific technologies and platforms (e.g. Solidity), other tools can provide different results. Our results must be evaluated in the context of informatics engineering and IS courses that include blockchain topics. Third, at this stage we did not yet presented both forms of contracts to the same participant. Therefore, we evaluated two separated instantiations of a legal and a smart contract, but the results may differ if the respondents had access to both contracts. On one hand, the access to both types of contracts could improve understandability (e.g. contrast specific parts to clarify the clauses). On the other hand, reading two contracts instead of one is an additional effort to the participants. The integration - in the form of a single contract that merge digital and physical form; or with a system that aligns/synchronizes its clauses is a promising line of research. And to finalize the translation of the contract for Solidity is influenced by the authors' interpretation of the content of the legal contract.

We hope that our work may contribute to include smart contracts as a key topic in current IS courses and to inspire researchers that aim to merge physical (legal) and digital (smart) forms of contract agreements. There are risks in this transformation that must be addressed by IS researchers, namely, avoiding errors in the interpretation of contracts (during the conversion process or in its final version) and proposing new solutions to align digital and physical forms of social agreements based in disruptive information technologies.

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