Using Combined Techniques for Requirements Elicitation: A Brazilian Case Study

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Abstract: Within the requirements engineering domain, requirements elicitation (RE) is one of the most difficult phases. Towards a successful and high-quality software development process, RE often suffers from information challenges such as ambiguity, incompleteness, and inconsistent data. Within this context, this research aims to analyze the contribution of RE combined techniques of both i) the elicitation of functional requirements (FR), and ii) non-functional requirements (NFR) at an Information Systems Higher Education (IS) course. Via a systematic literature review (RSL), 61 articles crawled from the Scopus database that meets the RE search criteria were fully reviewed and finally generated the list of RE. The top three REs (Interview, Prototyping, and Brainstorming) were then used to support the IS course case study with 56 students. Results showed that combined FR and NFR techniques improved the RE completeness and consistency when compared to every single technique isolatedly.

1 INTRODUCTION

Within the software development domain, requirements engineering is the most complex phase (Pandey *et al*., 2010; Fernandes *et al*., 2012; Buitron, *et al*., 2018). Within requirements engineering, the requirements elicitation (RE) step is dedicated to the discovery, extraction, and disclosure of users' needs (Alexa & Avasilcai, 2018). Thus, RE is understanding the users' needs.

Nevertheless, RE is a difficult task. It deals with information ambiguity, incomplete, and inconsistent data, given requirements are ofter not well-known before-hand (Vijayan *et al*., 2016). RE is thus much more than writing requirements only: it is discovering and understanding real problems of real-users (Araújo, Anjos, & Silva, 2015). Thus, problems and misunderstands needs are ofter one of the main factors why the projects fail (Gonzales & Leroy, 2011). A common reason for that is because users have difficulty expressing their requirements (Nuseibeh & Easterbrook, 2000). These difficulties usually lead to large faults in software projects such as incomplete and incorrect requirements (Mishra *et al*. 2008).

Traditional requirements engineering is often insufficient for requirements elicitation. They were not planned for constantly evolving nowadays environments thus leading to failures in software development (Knauss *et al*. 2018). On the other hand, agile methodologies are suitable for changes in both requirements and RE process during software development. Moreover, the agile combination of several RE techniques can improve the quality of functional requirements (FR) and non-functional requirements (NFR) elicitation (Asghar *et al*., 2017).

Thus, the objective of this research is to analyze the eliciting process of FR via a combination of both RE techniques and NFR, by comparing the combined use of RE techniques when compared to the usage of every single technique isolated. In addition to the Section, this research is composed of the following Section 2, Base Concepts and Research Framework; Section 3, Research Method; Section 4, Case Study; Section 5, Results; Section 6, Discussions; and Section 7, Conclusions.

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2 BASE CONCEPTS AND RESEARCH FRAMEWORK

2.1 Functional Requirements

FRs describe what software should do, or what it is expected to do (Dardenne et al., 1993; Alvertis *et al*., 2016). In this case, FRs express the users' needs. RFs should describe in detail the software functions, with inputs, outputs, and exceptions. FRs are the activities that the software must perform without worrying about real-world physical aspects (Buitron *et al*., 2018).

Thus, the RF description must be clear and precise towards the users' understanding capacities. FRs must be easy to understand so that developers can implement properly implement them. FRs must be complete and consistent. Completeness is all the requested services (Boehm, 2000). RFs cannot leave any doubts or contradiction.

2.2 Non-functional Requirements

NFRs define software operating requirements (Alvertis *et al*., 2016). It is an important technology definition: hardware and software standards (Younas *et al*., 2017). The NFRs specify the properties of the software (Pandey *et al*., 2010) and software behavior and its attributes (Buitron *et al*., 2018), such as software security mechanisms, distribution, and licenses (Younas *et al*., 2017). NFRs describe the quality of the software thus they can lead to a fail or success rate to any project (Asghar *et al*., 2017). Therefore, quality criteria should be considered an inseparable part of NFR eliciting process (Younas *et al*., 2017).

2.3 Requirements Elicitation Techniques

The identification of RE techniques was performed through a systematic literature review (SLR). The SLR is a method to identify and analyze works available in the scientific databases and answer research questions. Kitchenham and Charters (2007) mention that SLR uses a rigorous, reliable, and auditable method. We use the protocol proposed by these authors to perform the SLR. This protocol establishes strategies for bibliographic research and the identification and evaluation of articles. The protocol was carried out in two stages: planning and selection of articles; and presentation of the SLR results.

2.3.1 SLR Planning and Selection

The SLR planning consists of two items: definition of objective and definition of the research protocol. The objective of this SLR is to identify RE techniques, and the definition of the protocol was carried out in three steps presented below:

(1) **SLR Question.** RE is a topic addressed in different fields of knowledge and in this research, the field of software development was specified. Thus, the question defined for this SLR was: What are the RE techniques used in software development projects?

(2) **SLR Identification.** We use the Scopus database (https://www.scopus.com), as this database index works from the ACM Digital Library and IEEEXplore libraries. The search term used was: TITLE-ABS-KEY ((“Requirements elicitation” OR “requirements gathering”) AND (Techniques OR methods OR procedures OR tools OR artifacts or specification) AND (software OR system OR systems)).

(3) **SLR Selection Criteria.** We adopt inclusion, exclusion, and quality criteria for the selection of articles. The works were included in the research framework when they met the inclusion criteria but were eliminated from the research framework when satisfying one of the exclusion criteria.

2.3.2 SLR Results

The application of the search term in the Scopus database resulted in 1972 articles. We apply the inclusion, exclusion, and quality criteria to these articles, resulting in 61 articles. In most of the works, we found more than one RE technique. However, different nomenclatures have been found for similar techniques, such as the terms “questionary” and “survey”. We grouped the similar techniques and forty RE techniques remained. However, five of these techniques were most frequently cited: interview, questionnaire, prototyping, use case, and brainstorming.

We made a comparison between these five techniques most cited in RSL and the techniques most frequently used in the business context. The works of Kassab, Neill, and Laplante (2014) and Todoran *et al*. (2013) were used to assess the business context. Kassab *et al*. (2014) surveyed companies in 23 countries, and Todoran *et al*. (2013) conducted an exploratory study to understand RE in the context of cloud computing.

We identified three techniques present in both works and present amongst the five most cited in RSL:

(1) **Interview.** The technique most mentioned in the articles was the interview. It was cited in 45 of the 61 selected articles. Interviews are essential to gather information for new projects through questions and answers, in which the information collected is more in-depth, but involves a limited number of respondents (Saad & Dawson, 2018). Interviews can be structured, semi-structured, or unstructured. In structured interviews, all interviewees are asked about the same questions, while in unstructured interviews, the interviewer does not need to follow a list of questions (Pitula & Radhakrishnan, 2011). In semi-structured interviews, both situations are addressed. Semi-structured or unstructured interviews have the benefit of looking for new and unexpected ideas (Smith, Strauss & Maher, 2010). For Gill, Zaidi, and Kiani (2014) the success of this technique depends on the interviewer's ability to conduct the interview and collect the requirements.

(2) **Prototyping.** It is an incomplete version of the software, which can be either disposable or evolutionary (Younas *et al*., 2017). The disposable prototype is used only to understand the user's requirements and perception, while the evolutionary provides a basis for the user's final version. This technique facilitates user engagement and the early identification of problems that may affect the usability of the software (Ramakrishnan *et al*., 2014). However, according to Gill *et al*. (2014), a disadvantage of this technique is the expenditure of time and resources.

(3) **Brainstorming.** It is a way to tune the user's mind concerning the requirements (Younas *et al*., 2017). It is performed in two phases: In the first, ideas are collected and in the second, discussions about the collected ideas are carried out (Younas *et al*., 2017). This technique is used for the massive collection of data for further refinement of ideas (Al-Qudah, Cristea, & Lei, 2013). However, Sadiq *et al*. (2009) claim that this technique is not suitable for eliciting security requirements, that is, it does not provide a consistent set of security requirements. The user experience must also be considered for the correct use of this technique, as users with more experience can better express their needs. In this case, techniques such as brainstorming are effective (Mishra *et al*., 2018). Another interesting feature of this technique is the stimulus to creativity. Caleb-Solly *et al*. (2014) used brainstorming sessions to stimulate and provoke ideas amongst the participants and achieved more creative and unexpected ideas.

2.4 RE Techniques Practice

This section presents some works related to the combination of RE techniques. Saad and Dawson (2018) highlighted that the use of only one technique for RE can result in an inadequate specification, which affects the quality of the requirements. They argue that there is a need to combine techniques for the RE process to be efficient and successful. The SLR found three studies that addressed the combination of RE techniques (Fernandes *et al*., 2012; Lim & Finkelstein, 2012; Gill *et al*., 2014).

Fernandes *et al*. (2012) combined the Six Thinking Hats technique with the Brainstorming technique. Six Thinking Hats is a creative thinking technique, in which each hat is assigned a color: blue, green, red, yellow, black, and white. The technique proposes that each person in the group thinks actively and differently. They concluded that this approach could improve user engagement in RE.

Lim and Finkelstein (2012) developed a method (StakeRare) to identify and prioritize software requirements with a collaborative approach. This method is developed in four stages: identification and prioritization of stakeholders based on their influence on the project; interviews based on the identified profile, to specify the initial requirements of the software, carried out using the focus group technique; RE of each stakeholder based on a collaborative approach; and prioritizing stakeholder requirements.

Another method found in the literature was described by Gill *et al*. (2014). They proposed the Contributory Appreciative Inquiry method for RE, composed of six phases: use of the artificial intelligence technique to highlight future requirements; a compilation of a high-level requirements' list; categorization of requirements into contributory points; mapped requirements are analyzed with stakeholders through brainstorming sessions; and finally, the requirements are listed and specified.

2.5 Research Framework

The research framework consists of two research propositions and a description of the variables that make up the propositions. The propositions consider only the three RE techniques most cited in the literature and most used in the business context: interview, prototyping, and brainstorming.

2.5.1 Research Propositions

The research framework is outlined in Figure 1. It consists of two research proposals, which suggest that

the combined use of RE techniques improves the quality of RF and NFR.

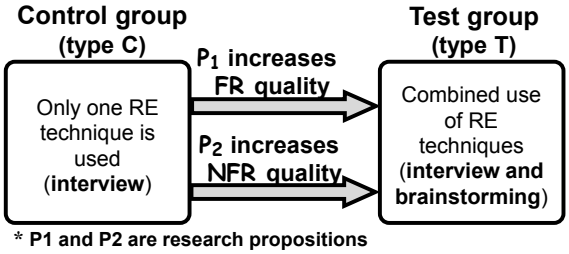

Figure 1: Research framework.

Type C The teams that belong to this group use only the interview as a RE technique

Type T The teams that belong to this group combine the use of interview and brainstorming techniques for RE

It should be noted that the prototyping technique was used by all teams, as the quality of the RF and NFR was assessed by the prototype.

The research framework presents two propositions to be verified in this research:

P1. Teams that use more than one RE technique produce a better-quality functional requirements (FR) specification.

P2. Teams using more than one RE technique produce a better-quality non-functional requirements (NFR) specification.

These propositions are based on variables that are described below.

2.5.2 Research Variables

The research framework has three types of variables: independent, dependent, and control. It is possible to manipulate the data of the independent variables and they influence the dependent variables. The dependent variables are the results of the influence of the independent variables. Finally, the control variables are considered variables that influence the results of the dependent variables and can be used to explain the results (Creswell, 2007).

Independent Variable. It is the variable whose manipulation allows the study of the impact on the quality of the elicited requirements.

(1) Combined use of techniques. Refers to the number of techniques used in RE: level 0 refers to the use of only one RE technique; and level 1 refers to the combined use of more than one RE technique.

Dependent Variables. These are two variables that represent the quality level of RF and RNF. In this research, quality refers to two attributes: completeness and consistency of requirements.

(1) Quality of RF. It represents the correct elicitation, in terms of completeness and consistency of the RF. This variable has three levels: level 0 refers to a low-quality RE; level 1 refers to a medium quality REç and level 2 refers to high-quality RE.

(2) Quality of RNF. It represents the quality of RNF in terms of completeness and consistency of RF and has the same levels as the previous variable.

Control Variables. The research model consists of two control variables that are associated with the involvement of teams in the RE process.

(1) Motivation. It refers to the team's motivation in the entire ER process evaluated by two criteria: assiduity and punctuality of the team in interactions. This indicator has three levels: level 0, which represents a team with a lack of attendance and lack of punctuality; level 1, which represents a team with a lack of attendance or lack of punctuality; and level 2, which represents a team with assiduity and punctuality. Assiduity and punctuality were used as criteria for measuring motivation, as according to Grotta (2019), they can be used to assess the motivation of a team.

(2) Communication. It refers to communication in the RE process between team members and between the team and the client. This indicator has three levels: level 0, which represents a lack of communication between team members and between the team and the client; level 1, which represents a lack of communication between team members or between the team and the client; and level 2, which represents adequate communication between team members and between the team and the client.

3 RESEARCH METHOD

The research proposed in this work is an exploratory study. According to Creswell (2007), an exploratory research aims to offer information about the object of study and guide the formulation of hypotheses for future research. This research explores the influence of using more than one RE technique on the quality of FR and NFR. It should be noted that this study is qualitative and cross-sectional research, as the data were collected only once.

This section describes the research steps and the methodological procedures for collecting and analyzing data.

3.1 Research Phases and Strategy

The research consists of five phases. The first phase comprises the literature review, in which the basic

research concepts were described. In the second phase, we developed the research framework composed of the research proposals and variables, based on the literature review. Then, in the third phase, we define the methodological procedures, which are presented in this section. In the fourth phase, we collected the data that is presented in sections 4 and 5. In the fifth and last phase, we carry out the results' analysis and the research conclusions.

We adopted the case study as a research strategy because according to Eisenhardt (1989) the case study allows the researcher to flexibly analyze the findings of data collection.

3.2 Case Study Protocol

The research protocol describes the selection of research participants and the requirements that must be specified by the teams. Finally, we describe the interaction plan between researchers and participants for data collection.

3.2.1 Selection of Research Participants

We performed the case study in the second half of 2019, with undergraduate students of an Information Systems course at the University of São Paulo. We selected a morning class from the third semester of the course. The choice of a morning class made it possible to have students with greater availability to perform the research activities because few students of this morning class had professional activities or internships.

The selected class had 56 students, enough for the composition of several teams for the software development project needed to analyze RE techniques.

3.2.2 Requirements Specified by the Teams

According to the protocol, teams must elicit requirements for an employee's evaluating system of a private company. The results must be presented using a prototype. The requirements to be elicited include:

(1) **Functional Requirements.** Twelve RFs were defined for employees' evaluation, which was categorized into three groups: performance, behavior, and social and personal skills.

(2) **Non-functional Requirements.** Five NFRs related to design and user interface were defined: responsive design; intuitive interface with an attractive appearance; concepts and text familiar to the user; data must have consistency and follow a standard; and warning messages about users' actions.

In the end, the teams must deliver a prototype with the requirements. In this way, the prototyping technique is used by all teams.

3.2.3 Interaction Plan with Teams

We have defined four interactions for evaluating team activities and outcomes.

(1) **First Interaction.** We present the project proposal to the teams. In this stage, we defined the teams, the activities, and the interaction schedule with a duration of four months.

(2) **Second Interaction.** In this interaction, all teams must use the interview technique for RE. The FR and NFR are reported to the groups and the criteria for the elaboration of the prototype. It is expected with this interaction that the teams understand the software requirements to start the prototype development. Teams were also asked to create user stories based on this interaction, which should be delivered in the third interaction.

(3) **Third Interaction.** In this interaction, the teams use interview and brainstorming techniques. The goals are to verify the work developed by the teams since the second interaction, analyze the requirements specification elaborated by the teams, and clarify teams' doubts. During this interaction, we evaluate the motivation and communication of the team in carrying out the activities.

(4) **Fourth Interaction.** This is the last interaction. The teams deliver the final version of the prototype. We re-evaluated the team's motivation and communication in carrying out the activities. Finally, team members must answer an anonymous questionnaire about the project.

4 CASE STUDY

This section describes the case study characteristics. First, we describe the teams' characteristics, and then we describe the control we did on the case study external variables, which we sought to keep constant so as not to influence the research outcomes.

4.1 Teams' Characteristics

We formed ten teams with the 56 students. Six teams with six students and four teams with five students. We surveyed each student's school performance. This made it possible to form teams with similar school performance. This activity was carried out in the first interaction with the teams. The results are shown in Table 1.

Table 1: Teams' characteristics.

Teams	Members number	School performance (0 to 10)	Type of team
E01	6	6.1	Test
E02	6	6.4	Test
E03	5	6.0	Test
E04	5	6.4	Test
E05	6	6.2	Control
E06	6	6.7	Control
E07	5	6.7	Control
E08	5	6.0	Control
E09	6	6.0	Test
E10	6	6.8	Control

4.2 Case Study External Variables

We tried to keep constant the variables that are not part of the research framework to allow that only the use of techniques influences the RE process. Amongst the variables that were kept constant, the following stand out: (1) the activities in all teams were coordinated by the same researcher; (2) performance assessment of all teams was also carried out by the same researcher; (3) we describe the requirements to all teams in a similar way; (4) the time to do the activities was the same for all teams, that is, four months to develop the project and four interactions with the researcher; (5) GitHub (https://pages.github.com) was used by all teams to develop the project, which is a free platform on which several users can work on the same project; and (6) the number of students per team was almost the same since teams were formed with six or five students.

The teams' school performance was similar: the control group had an average of 6.5 and the experimental group 6.2. Thus, the teams' school performance remained very close, not being a variable of influence on the results of the study.

5 RESULTS

Table 2: Requirements' quality level.

Group	Number of techniques	Team	FR (P1*)	NFR (P2)
Control	1	E08	0	0
Control	1	E10	1	0
Control group performance (%)			25,0	0,0
Test	2	E01	2	2
Test	2	E02	1	1
Test	2	E03	1	0
Test	2	E04	2	1
Test	2	E09	1	0
Test group performance (%)			70,0	40,0

* 0: low-quality; 1: medium quality; 2: high-quality

Table 2 shows the quality levels of the requirements obtained by the teams. In proposition P1 we analyzed the influence of the use of ER techniques on the quality of RF, and in proposition P2 we analyzed the influence on the quality of RNF.

The E05, E06, and E07 teams did not deliver the prototype, so we disregarded the results of these teams. The teams in the experimental group used to interview and brainstorming techniques, and the teams in the control group used only the interview.

We calculate the performance of the groups by dividing the sum of the quality levels achieved by the teams, by the maximum quality level possible. For example, the performance of the control groups concerning the FR was 25.0%, that is, $(0 + 1)/(2 + 2)$.

We expected that the FR and NFR of the experimental group would be of higher quality than the control group. The results confirmed both propositions. In the P1 proposition, higher quality for the FR was expected, and the teams in the experimental group performed 45.0% higher than the control group. Similarly, in proposition P2, the higher quality was expected for the RNF, and the teams in the experimental group performed 40.0% higher than the control group.

6 DISCUSSIONS

We performed the analysis using the research control variables: motivation and communication. The analysis was based on data collected from interactions between the researcher and the teams, and the anonymous questionnaires submitted to students. Table 3 shows the results for propositions P1 and P2 and of the control variables.

Table 3: Research propositions.

Group	Team	P1* (FR)	P2 (NFR)	Motivation	Communication
Control	E08	0	0	2	0
Control	E10	1	0	2	2
Performance (%)		25,0	0,0	100,0	50,0
Test	E01	2	2	2	2
Test	E02	1	1	2	0
Test	E03	1	0	1	1
Test	E04	2	1	2	2
Test	E09	1	0	2	0
Performance (%)		70,0	40,0	90,0	50,0
Difference (%)		45,0	40,0	-10,0	0,0

* Research propositions
0: low-quality; 1: medium quality; 2: high-quality

Propositions P1 and P2 were confirmed by the research. The use of more than one RE technique has increased the quality of FR and NFR in terms of completeness and consistency. In the case of FR, the experimental teams - used more than one technique - had a performance of 70.0%, being 45.0% superior to that of the control teams - used only one technique. Likewise, the experimental teams performed 40.0% higher than the control teams concerning NFR. The results were very close for both RF and RNF. It can be inferred that the improvement achieved in the quality of the requirements did not depend on the type of requirement. The results corroborate the claims of Saad and Dawson (2018) that the use of only one RE technique can result in an inadequate specification that affects the quality of the requirements.

The control variables had no significant difference between the control and test groups. This shows that they did not influence the result and reinforces the evidence that quality improvement in RF and RNF occurred due to the use of more than one RE technique. The first control variable - motivation - was assessed by students' attendance and frequency in interactions. The experimental group was 10.0% lower than the test group. It can be inferred that improvement in RF and RNF quality was not associated with the team's motivation.

The second control variable - communication - was evaluated by two aspects: communication between team members and between the team and the client. The performance of the team's communication was the same for the experimental group and the control group. There was no difference between the groups, and it can be inferred that the improvement in the quality of RF and RNF was not associated with team communication.

7 CONCLUSIONS

The goal of this research was to analyze the influence of the combined use of RE techniques in the quality of FR and NFR. To achieve this goal, we carried out qualitative and exploratory research based on a case study involving 56 undergraduate students during the second semester of 2019. It should be noted that the research has limitations, of which the following stand out: (1) researcher's bias in analyzing and interpreting the collected data; (2) the educational environment, in which the case study was applied, has differences from the business environment, where software projects are developed under different goals, strategies, and human conflicts; and (3) the method used does not allow the generalization of results to other contexts.

The results confirm that the combined use of RE techniques improved the completeness and consistency of the RF and RNF. It was also possible to observe two control variables: motivation and communication. These variables had no positive association with the result.

The use of more than one technique for RE to improve the quality of requirements. This result has a similarity with the research methods recommendations, in which the use of alternative methods or data from different sources increases the rigor of the method (Yin, 2014). Therefore, we suggest for future research the analysis of RE techniques that have complementarity in terms of source or method of data collection.

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