A strategy for building shared understanding in requirements engineering activities

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Abstract. The requirements allow the development team to clearly understand the needs that the customer intends to be solved by the system, in this sense, understanding the context, capturing, negotiating, specifying, verifying, validating, and prioritizing the requirements may seem a relatively simple task, but there is a need to have a correct communication, and throughout this process, many changes and reprocesses occur due to misinterpretation or lack of information, in addition to considering that in the teams that perform these activities participate people from different disciplines, business units, cultures, with different levels of experience and therefore, each one will have different ways of perceiving the tasks, the key problems, which give meaning to the requirements according to their situation and knowledge, without having a joint base of homogeneous understanding within the team. Therefore, this work proposes a strategy for the construction of a shared understanding in the activities of requirements engineering, where its completeness, usefulness, and ease of use were validated, through an experiment executed as part of the development process of a software tool for the management of information and data processing of an agricultural and livestock association in Cauca. Using the conceptual, methodological, and validation cycle of the multi-cycle action research methodology, it was concluded that the strategy is complete and useful, but it is not easy to use, because its definition contains several elements that are difficult to handle, and it lacks adequate support to support and facilitate its application.

Keywords: Shared understanding, Requirements engineering, Requirements, Strategy.

1 Introduction

Software Engineering provides a set of methods and techniques for the creation of quality and reliable software. It covers all phases of the software development cycle, requirements, analysis and design, implementation, testing, and deployment. Much of the success of software development is due to a correct requirements management, where the needs that the software system must satisfy must be found and identified. requirements management is considered part of the first phase of software development in which the problem that the software product will solve is abstracted and understood, it

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is, essentially, a human activity where stakeholders are also identified and established relations with the development team [1]. The requirements allow the members of the development team to understand the needs that the client intends to be solved by the system, in this sense, understanding the context, capturing, negotiating, specifying, verifying, validating, and prioritizing the requirements may seem like a relatively simple task, but the need for successful communication is very high, and throughout this process there are many changes and re-processes due to misinterpretation, or lack of information, in addition to considering that the teams that carry out these activities They involve people from different disciplines, business units, cultures, with different levels of experience and therefore, each one will have different ways of perceiving the tasks, key problems, which makes sense of the requirements according to their situation and knowledge, without counting on a base joint homogeneous understanding within the team. Shared understanding refers to the degree to which team members agree on the steps of a work process, the meaning of those steps, the order, the relationship of activities, and their communication [2]. Considering this, the knowledge creation process implies participation, collaboration, and the achievement of a shared understanding [3]. Carrying out correct management of the communication and understanding of the requirements process is one of the main elements for its success, because there may be different interests with different expectations of understanding and fulfillment that can produce misinformation that, by not being treated correctly, it can generate gaps in communication and understanding between stakeholders and the development team [4]. Therefore, this paper proposes a strategy for the construction of the shared understanding in the requirements engineering activities, which was validated its completeness, usefulness, and ease of use through an experiment executed as part of the development of a software tool for information management and data processing of an agricultural and livestock association in Cauca - Colombia.

The paper is structured as follows: Section 2 describes the methodology, the conceptual, methodological and validation cycle of the methodology used, and section 3 describes the conclusions.

2 Methodology

This research was developed following the multi-cycle action-research methodology with bifurcation [5], for which cycles were followed: conceptual cycle, methodological cycle, and evaluation cycle.

2.1 Conceptual cycle

This cycle consisted of conducting a review of the related works that could support the definition of the proposal, its subsequent construction, and the correct application to validate it, which is why the most significant related works for this project are shown below:

In [6] a theory of coordination and communication is proposed in software organizations based on shared understanding, where it is highlighted that coordination and

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communication are essential and problematic elements. The role, value, and use of shared understanding in software engineering are investigated in [7], showing a practices compilation, as well as a roadmap to improve knowledge and practice in this area. For his part in [8] it addresses the influence of team distribution on the success of the project with a shared understanding approach. The theory of shared mental models is used for the construction and maintenance of shared understanding. In [9] communication is analyzed, through shared understanding, of the underlying concepts or relationships of a multidisciplinary team in the development of a mobile application. Similarly in [10] communication and the development of shared understanding based on the language are emphasized. The semantic alignment process is investigated by which stakeholders achieve a shared understanding in the development of software system requirements. On the other hand, in [11] analysis is made of how culture affects the shared understanding of requirements engineers, as well as in the organization and progress of software projects. In [12] the role of cognitive elements is investigated to improve the clarity of the user's story, for which a set of writing elements from different domains is proposed in order to mitigate ambiguity and improve the shared understanding. In [13] a process is proposed to achieve a shared understanding based on the construction of meaning through knowledge of the group and the constructive resolution of conflicts in requirements gathering workshops. For its part, [14] it provides a conceptualization of shared understanding as a sequence of state transitions at the group level based on the specialization construct of the team's mental model that participates in requirements. In [15] the importance of shared understanding is considered in the context of e-science projects, in addition, qualitative case studies are developed to generate recommendations to improve shared understanding in electronics science application requirements. Finally, in [16], a case study is carried out in three small organizations to understand and identify the factors that contribute to the lack of shared understanding in eliciting the non-functional requirements and what relation it has to its reworking.

2.2 Methodological cycle

The methodological cycle refers to the process of creating the strategy. In this sense, to meet this objective, the information previously obtained was analyzed, allowing the creation of a version of the strategy, which contains activities, tasks and steps that will allow executing the requirements engineering activities in a collaborative way, seeking to achieve a shared understanding during the whole process. For our context, a strategy refers to: a set of actions that are aimed at establishing a guide [5] to execute a requirements engineering activities that meets the expectations of the client and the development team of the product to be built.

To build an adequate strategy, it is first necessary to be clear about the requirements engineering activities, this in order for it to be solved and completely guided by the strategy defined here. Accordingly, requirements engineering refers to the process of collecting, analyzing, and verifying the needs of the client or user for a system, delivering a correct and complete software requirements specification [17]. This process consists of the following activities [18]:

- To understand the context in which the system to be developed will be executed

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- To capture the necessary information according to the stakeholders and sources considered
- To negotiate with stakeholders, the solutions to the problems identified
- To specify each of the requirements and needs identified in a defined notation
- To verify that the requirements are complete, unambiguous, verifiable, and correctly detailed
- To validate requirements by presenting them to stakeholders in order to ensure that needs and expectations have been properly captured and expressed
- To prioritize requirements according to the value that stakeholders place on the vision of the system, the urgency, time constraints, complexity or preferences

On the other hand, shared understanding refers to creating a new joint perspective that arises from the initially individual contributions of the participants, and from the exchange of knowledge, flow of communication and holding of debates that allow coordinating actions in order to achieve the objective of the collaborative activities they carry out [19] [20]. In this sense, the shared understanding for requirements engineering is an important determinant for performance, as well as a challenge in these heterogeneous groups [21], this is due to, the fact that those involved in each task may be using the same words for different concepts or different words for the same concepts without realizing it, making the final requirements not the most appropriate and each interpreting them differently [22]. Differences in the meaning assigned to key concepts or information can interfere with the productivity of collaborative work if they are not clarified up front [23], [24], [25].

Considering the above, to define and incorporate collaboration into said strategy, the collaborative engineering design approach was followed [26], which addresses the challenge of designing and implementing collaborative work practices for recurring high-value tasks and transferring them to professionals to execute it themselves without the ongoing support of a collaborative professional expert [22]. In this sense, a strategy called "*Brainstorming for shared understanding*" was defined, in order to guide the entire requirements engineering process, which is made up of activities, tasks and steps. Specifically, to comply with a strategy that builds shared understanding and therefore collaboration, each activity must have the following tasks in terms of its structure (See **Fig.** *1*).

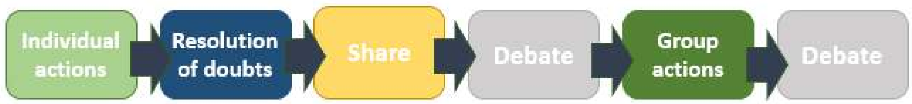

Fig. 1. Tasks structure of each activity

The individual actions refer to the moment in which each participant must obtain individual results to fulfill the activity objective, based on the needs for the construction of tacit knowledge (that which is acquired through experience itself) and which must subsequently become explicit at the time of materializing it in a result [27].

The resolution of doubts refers to the moment in which each participant solves those questions they have about the subject being analyzed

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Share refers to the moment in which each participant inserts a meaning, tuning in to the other groupmates in the group, who listen actively and try to capture the explanation or results given, using them to give meaning to the situation in question [28].

Debate refers to the moment in which a mutual construction of meaning is carried out, treating the differences of interpretation between the participants of the group through discussions with arguments and clarifications [29].

Group actions, is the moment in which the interpretation of meanings or actions carried out with the support and collaboration of all the participants of the group materialize to fulfill the activity objective

With the previous structure, each of the activities of the strategy proposed here was defined, considering, that this structure served as the basis to achieve the objectives of each activity as shown in the following figure (See **Fig.** ***2***).

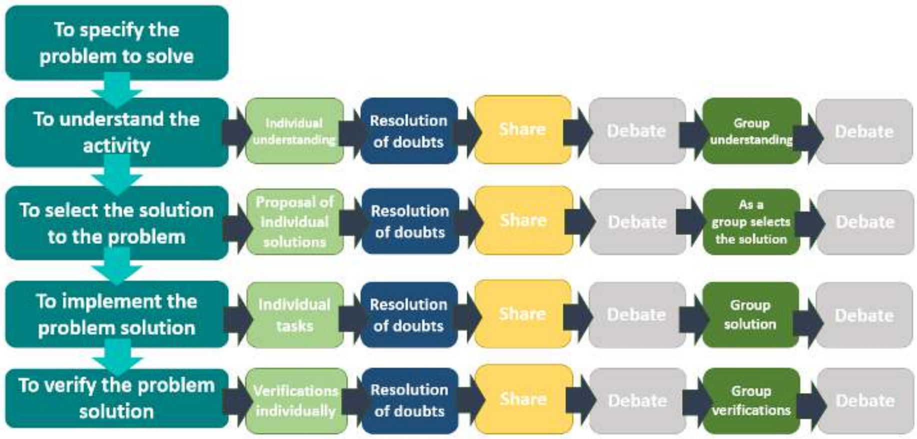

Fig. 2. Activities and tasks of the strategy

The objective of each activity of the strategy is shown below, with their respective inputs and outputs. In addition to what is shown here, it is important to determine that the execution steps, estimated time and their respective formats were defined for each of the tasks to guide each of the steps to be executed.

To specify the problem to solve: The objective of this activity is for the participants to know and contextualize themselves about the problem to be solved, the collaborative activity objective, and what they will have to execute throughout the brainstorming.

Inputs**:** The problem of collaborative activity, the collaborative activity objective, brief description of brainstorming

Outputs**:** None

To understand the activity: The objective of this activity is that each participant individually understands the problem to be solved and the collaborative activity objective and that in the same way, after the debates, an equal understanding is reached for all and where everyone agrees, which is can finally materialize into a deliverable made

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with the help of everyone, about the problem understood and the objective of the collaborative activity.

Inputs**:** Format to define doubts, format for defining individual ideas, format for discussion, format for the definition of group understanding, format for group understanding discussion

Outputs**:** Individual ideas, group defined idea

To select the solution to the problem: The objective of this activity is to select the solution that is going to be implemented by the group to solve the problem of collaborative activity, initially giving ideas of individual solutions, later, with the socialized ideas, they are categorized and according to these categories, the chosen solution is chosen and formalized with the contribution of all participants.

Inputs**:** Format for individual solution ideas, format to define doubts, format for discussion, format to define chosen solution, format for discussion of the chosen solution

Outputs**:** Individual solution ideas, ideas categorization, solution chosen to implement

To implement the problem solution: The objective of this activity is to define, and subsequently, execute the individual tasks that will allow solving the problem. Each participant will share their individual results, and after this, the complete solution of the problem will be formalized, together with the contributions of all the participants.

Inputs**:** Format for defining individual tasks, format for socializing results of executing individual results, format to define doubts, format for discussion, format to formalize the solution implemented in group, format for discussion of the implemented solution

Outputs**:** Defined individual tasks, individual tasks executed, formalization of the implemented solution

To verify the problem solution: The objective of this activity is to verify that the solution implemented by the group does solve the problem posed in the collaborative activity. For this, each of the participants defines possible scenarios where the solution of the problem is implemented, later socialization is made with the group, and from this, the scenarios in which there is a correct solution to the problem are defined in a group, to determine if it was executed correctly and complies with the request.

Inputs**:** Format for defining individual scenarios, format to define doubts, format for discussion, format to formalize scenarios where the group-defined solution is implemented, format for discussion of the verification carried out

Outputs**:** Individual scenarios, scenarios with the implementation of the solution defined in the group

With the previous strategy defined and considering the requirements engineering activities mentioned above, below, the correspondence of how the entire strategy will be carried out is shown in order to finally obtain a set of requirements that will meet the needs of the end users of the system and a shared understanding between these users and the development team (**Fig.** ***3***).

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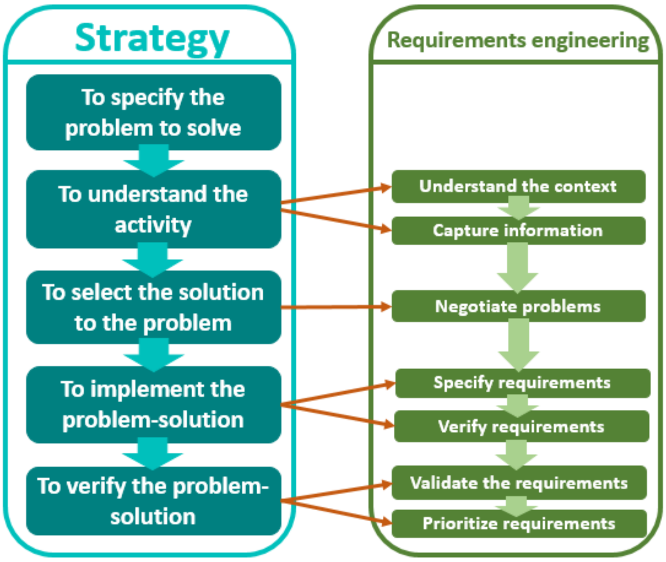

Fig. 3. Correspondence between strategy activities and requirements engineering activities

2.3 Validation cycle

This cycle made it possible to achieve the objective of inquiring about the completeness, usefulness and ease of use of the defined strategy, through its application in the developing process a software tool, for the management of information and data processing of an association livestock, it is important to clarify that the strategy was subjected to several revisions of its structure and its definition, carried out by a member of IDIS research group of the University del Cauca and a member of MIND research group of Unicomfacauca. In addition, a review session was held with an expert in group work and collaborative engineering and an expert in requirements engineering, who reviewed the strategy to indicate whether it had the necessary elements to satisfy these two areas. Several corrections were made to the strategy before it was implemented in practice. The experiment is summarized in the following sections.

Experiment Context

The entire strategy was applied in a real environment, where it was necessary to obtain the requirements for a software tool development for ASPROLGAN (Asociación de Productores Lácteos y Agro ganaderos del Municipio de Popayán), which is located in Popayán city, Cauca department - Colombia. It is a non-profit association made up of 94 associates who in turn influence 470 people who belong to their family nuclei; All these peasant and indigenous families have found in livestock a form of family sustenance. The association as an organization must support its administrative management processes such as: planning, organization, direction and control, but these processes are not currently being executed in the best way, because there is not enough, standardized,

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available information and accessible, where now it is managed manually. Therefore, the association's need is mainly to improve information management and data processing through the use of a software tool for the dairy sectors that belong to the ASPROLGAN association

For the implementation of the strategy, 8 members of the development team participated (including the project manager, 2 quality engineer, 3 developers, 2 analysts and 1 software architect) and 5 members of the association.

For the context of this work, the problem to be solved consisted in doing the requirements engineering process to finally obtain a set of requirements that a software tool should have that is in charge of the information management and data treatment processes in the dairy sectors of the indigenous and peasant community of the San Juan and San Ignacio villages belonging to ASPROLGAN. To solve the problem, a group was formed, where both the development team and the 2 members of the association had to follow the strategy outlined here and thus obtain the necessary requirements.

Experiment planning

The experiment objective was to inquire about the completeness, usefulness and ease of use of the proposed strategy for the shared understanding construction in the requirements engineering activities execution. In this sense, the research question was defined as: How complete, useful and easy to use is the strategy “Brainstorming for shared understanding” proposed here? This study had an analysis unit, which was the real context, where the requirements engineering activities was carried out for a software tool construction for information management and data treatment in the dairy sectors of the indigenous community and peasant from the San Juan and San Ignacio villages belonging to ASPROLGAN, using the proposed strategy.

Hypothesis. Considering the research question, it is intended to evaluate the following hypotheses:

- The strategy "Brainstorming for shared understanding" is complete[1] with respect to having the necessary elements for the shared understanding construction and the requirements engineering activities execution
- The strategy “Brainstorming for shared understanding” is useful[2] for the shared understanding construction and the requirements engineering activities execution
- The “Brainstorming for shared understanding” strategy is easy to use[3] for shared understanding construction and the requirements engineering activities execution

In order to refine the previous hypotheses, the following specific hypotheses with their respective variables were raised (See **Table *1***):

[1] Completeness in this context refers to the fact that the strategy contains the necessary elements, steps and support

[2] Utility in this context refers to the fact that the strategy is organized and consistent in its definition to achieve what is necessary

[3] Ease of use in this context means that the strategy contains instructions, guidelines, supporting elements that are understood and can be used without additional support

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Table 1. Experiment hypothesis.

	Hypothesis	Variables
Completeness	H.1.1 Users who apply the proposal perceive that the activities, tasks and steps are sufficient for the shared understanding construction	It represents the completeness degree perceived by each person when applying the strategy. It is a perceptual judgment of the completeness of the proposal when building shared understanding
	H.1.2 Users who apply the proposal perceive that the activities, tasks and steps are sufficient for the requirements engineering activities execution	It represents the completeness degree perceived by each person when applying the strategy. It is a perceptual judgment of the completeness of the proposal when executing the requirements engineering activities
Utility	H.2.1 Users who apply the proposal perceive that the strategy is useful for the shared understanding construction	It represents the utility degree perceived by each person when applying the strategy. It is a perceptual judgment of the utility of the proposal when building shared understanding
	H.2.2 Users who apply the proposal perceive that the strategy is useful for the requirements engineering activities execution	It represents the utility degree perceived by each person when applying the strategy. It is a perceptual judgment of the utility of the proposal when executing the requirements engineering activities
Ease of use	H.3.1 Users who apply the proposal perceive that the strategy is easy to use for the shared understanding construction	It represents the perceived degree ease to use with which a person can apply the strategy. It is a perceptual judgment of the effort required to apply the proposal when build shared understanding
	H.3.2 Users who apply the proposal perceive that the strategy is easy to use for the requirements engineering activities execution	It represents the perceived degree ease to use with which a person can apply the strategy. It is a perceptual judgment of the effort required to apply the proposal to execute the requirements engineering activities

Table *2* Summarizes the activities designed for the experiment development, specifying its expected duration and the support instruments that would be used for its development.

Table 2. Experimentation activities summary

Activity	Planned duration	Support instruments
Activity 1: Group organization and information delivery	15 minutes	Documentation with the general context and ASPROLGAN needs
Activity 2: Strategy implementation	15 hours	Input and output formats for strategy activities
Activity 3: Questionnaire fill out	10 minutes	Survey

Execution of the experiment

The following table shows and details how each of the activities of the experiment was executed (**Table** *3*):

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Table 3. Time invested in each activity

Activity	Time invested
Activity 1	10 minutes
Activity 2	5 sessions of 4 hours each
Activity 3	10 minutes

- *Activity 1*: This activity aimed to socialize and contextualize in a general way what the experiment was. An oral presentation was made in order to inform the participants of how the experiment would be carried out, about the activities that would be developed, in addition to making known, clarifying some concepts used in it, and to socializing in general terms which ones were the ASPROLGAN needs.
- *Activity 2*: The objective of this activity was to execute each of the activities, tasks and steps proposed by the strategy, for each of the strategy activities, independent sessions were held as follows:
  - To specify the problem to solve: It was announced that for this experiment the problem was to obtain a set of necessary requirements that would satisfy the association needs for the management of its information and data processing through a software tool.
  - To understand the activity: An informal contextualization meeting was initially held between the development team and the association members, in order to publicize their context and the specific needs that the software tool should cover and clear up doubts on the part of the development team. After that, each participant defined their understanding of the context and needs in a format, which were shared with the other members of the development team. This information was then categorized, doubts were solved, debated and finally a specification was made in a format, where everyone participated to define the needs identified in the context, which was also debated to reach a consensus of what was stipulated.
  - To select the solution of the problem: Each member of the development team filled out a form that specified how the software tool intended to solve each of the identified needs. Then, these formats were socialized, doubts were solved, categorized, those solutions were chosen, which according to the perception of the development team were the best for the needs, they were discussed and finally, according to these chosen solutions, they were completed and improved with everyone's contribution and with the necessary discussions. These solutions were shown to the association members who gave their points of view, solved some doubts and problems encountered, and in this way the formats presented were corrected.
  - To implement the problem solution: The established solutions were divided and assigned to members of the development team, who individually defined the epic stories, user stories, SRS (Software Requirements Specification), and solution prototypes, which corresponded to them. With this done, doubts are resolved, each member of the team socialized what they did, debates are generated with the disagreements found, finally contributions are made between all to improve and correct the deliverables and form a complete solution that is part of the

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requirements specification, with this generates the necessary discussions. With this ready specification, a verification is made with people external to the development team to determine if the requirements are complete, unambiguous, verifiable and expressed with an appropriate level of detail, according to the results they are corrected and improved.

- To verify the problem solution: A complete prototype is delivered to each of the development team members and to the association members, where each one defines possible scenarios that can happen within the association for be solved with the presented prototype, doubts are solved, the information is socialized obtained, the debates are generated, with the support of all, the errors detected are corrected, the prototype is improved according to the defined scenarios and debates are generated. With a more stable version and where everyone agrees, all requirements are prioritized according to the needs of the association and the time that will be taken to develop the application

- *Activity 3*: In this last activity, the objective was that the participants answered a survey, which made it possible to evaluate the completeness, usefulness and ease of use of the applied strategy.

Results and analysis

The qualitative analysis was carried out from the surveys completed by the development team members and the association members who participated in the strategy application. The responses to the survey were based on the Linkert scale, which is a form of measurement that allows evaluating attitudes and knowing the agreement degree on a set of statements. The measurement scale of the survey was defined as follows: value 1 for the totally disagree option, value 2 for the disagree option, value 3 for the neutral option (neither agree nor disagree), value 4 for the agree option and 5 for the totally agree option. From the hypotheses initially drawn, the following null hypotheses were raised:

- $H.1.1_0$, $\boldsymbol{\pi}_1 <= 60\%$, where $\boldsymbol{\pi}_1$ is the perception percentage that evaluates that the activities, tasks and steps of the strategy are sufficient for the shared understanding construction
- $H.1.2_0$, $\boldsymbol{\pi}_2 <= 60\%$, where $\boldsymbol{\pi}_2$ is the perception percentage that evaluates that the activities, tasks and steps are sufficient for the requirements engineering activities execution
- $H.2.1_0$, $\boldsymbol{\pi}_3 <= 60\%$, where $\boldsymbol{\pi}_3$ is the perception percentage that evaluates the strategy usefulness for the shared understanding construction
- $H.2.2_0$, $\boldsymbol{\pi}_4 <= 60\%$, where $\boldsymbol{\pi}_4$ is the perception percentage that evaluates the strategy usefulness for the requirements engineering activities execution
- $H.3.1_0$, $\boldsymbol{\pi}_5 <= 60\%$, where $\boldsymbol{\pi}_5$ is the perception percentage that evaluates the strategy ease of use for the shared understanding construction
- $H.3.1_0$, $\boldsymbol{\pi}_6 <= 60\%$, where $\boldsymbol{\pi}_6$ is the perception percentage that evaluates the strategy ease of use for the requirements engineering activities execution

From the null hypotheses the following alternative hypotheses were obtained:

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- H.1.1, π_1 > 60%, where π_1 is the perception percentage that evaluates that the activities, tasks and steps of the strategy are sufficient for the shared understanding construction
- H.1.2, π_2 > 60%, where π_2 is the perception percentage that evaluates that the activities, tasks and steps are sufficient for the requirements engineering activities execution
- H.2.1, π_3 > 60%, where π_3 is the perception percentage that evaluates the strategy usefulness for the shared understanding construction
- H.2.2, π_4 > 60%, where π_4 is the perception percentage that evaluates the strategy usefulness for the requirements engineering activities execution
- H.3.1, π_5 > 60%, where π_5 is the perception percentage that evaluates the strategy ease of use for the shared understanding construction
- H.3.1, π_6 > 60%, where π_6 is the perception percentage that evaluates the strategy ease of use for the requirements engineering activities execution

From the results obtained in the surveys, it was obtained that:

- For the analysis of activities, tasks and steps of the strategy to determine if they are sufficient for the shared understanding construction, the participants' perception percentage is 68.53%, which determined that H.1.1 can be accepted, it can be said that the strategy is complete for the shared understanding construction
- For the analysis of activities, tasks and steps the strategy to determine if they are sufficient for the shared understanding construction, the participants' perception percentage is 72.3%, which determined that H.1.2 can be accepted, it can be said that the strategy is complete for the requirements engineering activities execution
- For the analysis of the strategy usefulness, the participants' perception percentage is 75.4%, which determined that H.2.1 can be accepted, it can be said that the strategy is useful for the shared understanding construction
- For the analysis of the strategy usefulness, the participants' perception percentage is 67.6%, which determined that H.2.2 can be accepted, it can be said that the strategy is useful for the engineering requirements activities execution
- For the analysis of strategy ease of use, the participants' perception percentage is 55.2%, which determined that H.3.1 can be rejected, it can be said that the strategy is not easy to use for the shared understanding construction
- For the analysis of strategy ease of use, the participants' perception percentage is 46.5%, which determined that H.3.2 can be rejected, it can be said that the strategy is not easy to use for the requirements engineering activities execution

With the specific hypotheses accepted, it can be inferred that the main hypotheses are accepted, determining that: the "Brainstorming for shared understanding" strategy is complete and useful in the sense that it has the necessary elements for the construction of shared understanding and the execution of requirements engineering activities. However, the strategy is not easy to use for the construction of shared understanding and the execution of requirements engineering activities.

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3 Conclusions and future work

This paper proposes a strategy for the shared understanding construction in requirements engineering tasks following the conceptual, methodological, and validation cycle of the multi-cycle action-research methodology. The set of activities that are part of the strategy is shown and defined, as well as the correspondence and compatibility with the activities used in requirements engineering. The strategy was validated through an experiment carried out in the development process context of a software tool for information management and data processing of the ASPROLGAN livestock association. According to the validation carried out in this context, with the hypotheses of H.1.1 and H.1.2 it can be concluded that the participants perceived that the strategy has sufficient elements for the construction of shared understanding and the requirements engineering activities execution. Similarly, in the validation of hypotheses H.2.1 and H.2.2 regarding utility, it can be concluded that the strategy is useful because it was perceived to be organized and consistent in its definition. Regarding the ease of use of the strategy, validated in hypotheses H.3.1 and H.3.2, it can be concluded that the instructions, guidelines, support elements that it contains need additional support so that their understanding is more suitable, in such a way that this affected its ease of use. As future work, it is expected to make improvements to the strategy corresponding to its ease of use, to later be applied in other software development projects that allow its definition to mature.

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